AIR NAVIGATION

METEOROLOGY

◆

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AIR NAVIGATION
AND
METEOROLOGY

Second Edition

By

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PREFACE

Air pilotage or Aerial Navigation, the most important part of a pilot's training, is only touched upon very briefly in some of our Flying Schools. This, in a great measure, is due to the distinct lack of text-books available on the subject.

At the present time a student of Air Pilotage has to refer to numerous authorities in his endeavour to gain a thorough knowledge of navigation and meteorology. Considerable time is wasted in obtaining the necessary information, and further, the student expends a great deal of energy unnecessarily, learning much that is of no use to him.

Air Pilotage is by no means of a highly scientific nature. The average student will experience little difficulty in making himself thoroughly efficient by careful study and applying the knowledge thus obtained in a practical manner in the air.

There are no mathematical problems to solve; an occasional formula to be memorized and applied to the various problems as they arise.

Meteorology is a branch of navigation with which a pilot should be thoroughly conversant. Particularly in relation to Cloud Forms, Wind and Temperature. He will then realize the great assistance rendered him by the daily reports issued through the Weather Bureau, and how accurately they are able to forecast weather conditions.

The best authorities have been freely consulted in compiling this book, and due acknowledgment is made by the writer to the valuable assistance thus obtained to:

The weekly magazine "Aviation" for the chapter on "Ice Formation on Planes." It is undoubtedly, the most complete and valuable report yet compiled on the greatest of all hazards the navigator has to contend with.

PREFACE

The Pioneer Instrument Company, Brooklyn, New York, inventors of the Earth Inductor Compass, for the illustrative and descriptive data on instruments.

The Controller, H. B. M. Stationery Office, for reproductions from the Manual of Air Pilotage.

The monthly magazine "Popular Aviation" for the very latest data in Air Meteorology—Wind Charts—relating to the charting of the Winds of the Upper Air and the steps now being taken for the compiling and issuing of World Weather Maps, Information of vital interest to all Trans-oceanic flyers and seaplane pilots.

Rand McNally and Company, Chicago, for the reproduction of their Air Map of the United States and a Mercator's Chart of the World. The Air Map is a valuable addition to the aviation field and meets a long felt want.

The Department of Agriculture (Weather Bureau) for the information on Weather Maps and the illustrations on Cloud Forms, etc.

In an endeavour to meet the requirements of the student, the advice and suggestions of the instructors at many of the leading aviation schools throughout the country was sought and, as far as possible, embodied in the second edition of this book. Particular appreciation is extended to

Captain L. Ponton de Arce, U. S. Air Corps
Captain J. C. Bryan, U. S. Air Corps
Captain E. A. Dixon, R. F. C.
Lieut. Carl Dixon, U. S. Air Corps
Lieut. A. A. Yotz, U. S. Air Corps.

RICHARD DUNCAN.

December 1, 1928

INTRODUCTION

The second edition of *Air Navigation and Meteorology* has been entirely rewritten and considerably enlarged. In order to make the text clearer, additional diagrams, illustrations and reproductions of actual photographs have been included, and much new data added to the text.

The various subjects have been arranged in sequence most suitable for the student, and in accordance with the suggestions received from many of the leading aviation schools in the country.

Throughout the book a bold faced type has been freely used to aid the student in picking out the salient features of any particular section.

By referring to the Preface, it will be seen that no effort has been spared in obtaining data from the most reliable sources.

Beacons have been invaluable to the night-flying pilots of the Air Mail. In the establishing of Radio Beacons and the equipping of airplanes with radio, another step forward in the science of Air Navigation has been made. Navigation by Directional Wireless has already proved successful—as witness the army flight to Honolulu—and the difficulties presented by fog or other hazards no longer exist. For long distance flying it is ideal, being comparatively simple and accurate.

In the Chapter on Directional Wireless the principles involved are explained fully.

The ability to ''Fly Blind'' is an established fact, due to the development in and perfection of Navigation instruments, and particularly the Flight Indicator.

A pilot, flying an airplane equipped with the necessary instruments, should experience no difficulty in steering a correct course through the thickest fog. An excellent article, bearing out this statement, appeared in the July number of *Aero Digest.* The Ocker-Myer method of ''Blind Flying'' is well worth study-ing and Captain William C. Ocker and Flight Surgeon David A. Myers have rendered service of inestimable value to Aviation.

The chapter on instruments should be studied carefully. It is up-to-date and complete.

Aeronautical Meteorology has not received the attention or careful study it deserves on the part of the average pilot. In this book it is presented in a simplified, practical manner. Ability in forecasting weather and making use of Weather Reports adds considerably to the Safety Factor in flying, increases the efficiency of the pilot and reduces the so-called hazards of flying. With over two hundred Weather Bureau Stations, no difficulty should be experienced in receiving the desired information.

Transport Companies demand their Pilots be skilled Air Navigators, with the ability to steer the aircraft to its destination under the most adverse conditions.

This book has been written and compiled with a two-fold purpose: to serve as a text-book for the student, and as a reference book for the experienced pilot.

The Questions and Problems in the Appendix will enable the student to test himself thoroughly and are an excellent aid in self-instruction.

Maps, Charts and information of a special character may be secured from the various Government Departments concerned. The officials are very courteous and obliging, rendering willing service in anything that may further the progress of aviation.

To arrive at one's destination on time against the most adverse weather conditions is an essential qualification of the commercial pilot. The ability to fly an airplane is comparatively simple, but to steer the airplane from point to point, and across unknown territory, is only possible through the close study and application of Air Navigation. Supplied with the best maps procurable and the very accurate instruments now available, Air Navigation represents few difficulties.

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CHAPTER I.

AIR NAVIGATION.

Air Navigation in its present form is more correctly described as "Air Pilotage." It differs from Sea Navigation, in that courses are plotted and estimated positions reckoned by "Dead Reckoning" and the observation of Terrestial Objects; whereas, Navigation covers the aforesaid methods, but in the main depends upon the observation of Celestial Objects for the purpose of reckoning position and calculating courses.

> Dead Reckoning refers to all calculations where course and distance or Longitude and Latitude are calculated through the aid of the Air Speed Indicator and the Compass.

Dead Reckoning and the observation of Terrestial Objects are, therefore, the methods used by the Air Pilot to plot his course and steer the aircraft to the required destination.

Air Navigation covers the following subjects:

1. **Maps and Charts:** Map-reading and plotting courses, and being able from the map to locate any place or prominent object on the ground.
2. A general knowledge of the Earth as regards Longitude and Latitude, Measurement of Distances, and the Divisions of the Earth.
3. **The Magnetic Compass.**
4. **Instruments.**
5. **Meteorology:** Winds, Cloud Forms, Temperature, Air Pressures, Weather Maps, Weather Fore-casting, Atmosphere.

With a thorough knowledge of these subjects the problem of navigating from one point to another is simple, and no difficulty should be experienced by the pilot.

After plotting out the course on the map, various corrections have to be made to neutralize the effect of: wind, magnetic variation and deviation, all of which are explained clearly and fully in their order of application.

A study of, and the ability to read a map and apply the compass in unison with it, is the first and most important step in the training of a pilot desirous of becoming efficient, both as a pilot and an Air Navigator.

Without a good knowledge of "Air Pilotage," a pilot is useless.

Air Pilotage is not a subject requiring a technical or mathematical knowledge. It calls for practice and application alone, and any person with an ordinary school education, or the ability to read and write, is capable of becoming thoroughly efficient in the practice of Air Navigation.

MAPS.

A Map is a representation of the Earth's surface, or part of the Earth's surface, drawn to scale. It refers more particularly to land surfaces than to oceans and seas.

The methods by which maps are constructed requires a considerable knowledge of mathematics. Such knowledge is not necessary to the student of Air Navigation.

Distances on maps are horizontal, i.e., as the crow flies, and do not allow for the valleys and hills (contours and vertical intervals) which increase the distance between points on the ground.

"The correct representation of distances and bearings is the most important feature of a map."

Physical features on the ground such as hills, valleys, lakes, woods, roads, railways, etc., are shown on the map by means of conventional signs. A knowledge of how to read these is essential. Hills and valleys which stand out in relief on the earth's surface are the most important physical features to the pilot.

SCALE ON MAPS.

All maps are drawn to scale and the size of the scale determines the amount of detail which can be shown upon it.

The maps in general use, at the present time, are road maps common to the automobile driver, which differ considerably from specially constructed Air Maps, in that they give chief prominence to roads. Roads of average width, if drawn to scale, would be scarcely visible on a map; therefore, in order to make it easy to follow them, they are exaggerated considerably, so much so, that according to scale they would be from 200 to 300 feet in width. The increase in size of one feature naturally crowds out the others and creates distortion. Under these circumstances, it is impossible to give an exact repetition of all the minor features on the ground.

The most prominent objects on the ground such as main highways, railroads, lakes, woods, hills, towns and cities, are what the pilot checks his course by.

In Figure 1 maps of different scale are illustrated and from this it is clearly seen how detail is eliminated as the scale of the map is reduced.

Every map is drawn to scale, i.e., a certain distance on the ground is represented by a proportionate distance on the map: For example:

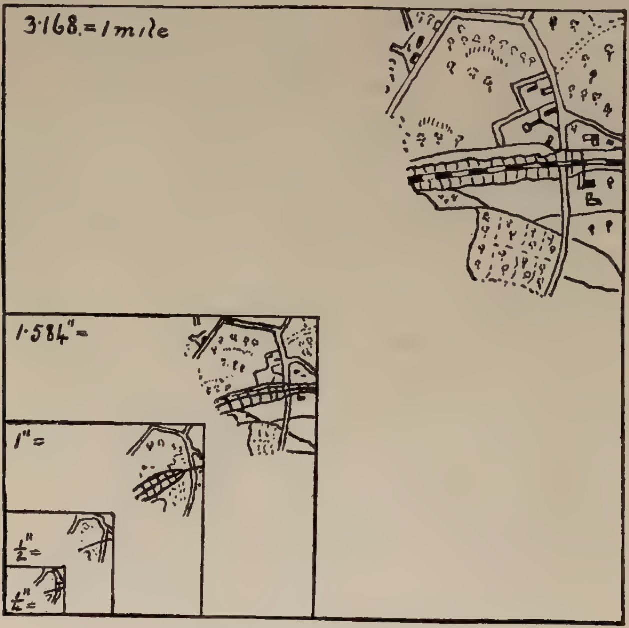
One inch on the Map represents one mile on the Ground. The scale of a map may be indicated in three ways. (Figure 2.)

1. By a statement of words—e.g. A quarter-inch to one mile.
2. A Representative Fraction—e.g. 1/63,360.
3. By means of a graduated scale line.

Preparatory to plotting out a course the pilot should first look for the scale of the map. This is generally found at the bottom right or left hand corner.

A Representative Fraction is spoken of as a Vulgar Fraction having the Numerator One. This means, that one unit of length on the map represents the number of the same units on the ground given by the Denominator. (Figure 2.)

Large Scale Maps are generally described as "six-inch" and "quarter-inch" maps, etc. This means six inches on the map represents one mile on the ground, and in like manner, a quarter-inch on the map represents one mile on the ground.



(Figure 1.) Map Reduction.

Small Scale Maps, on the other hand, are sometimes described as "10-mile" maps or "6-mile" maps, i.e., the map has a scale of one inch to 10 miles or one inch to 6 miles. (Figure 2.)

Particular note must be taken of the difference between the two methods of describing maps, otherwise confusion will result. Graphical examples of a Representative Fraction:

R. F. 1/63,360—denotes $\dfrac{\text{1 inch on map}}{\text{63,360 ins. on ground}}$

R. F. 1/220,000—denotes $\dfrac{\text{1 inch on map}}{\text{220,000 ins. on ground}}$

R. F. 1/15,840—denotes $\dfrac{\text{4 inches on map}}{\text{1 mile on the ground}}$

The third example may be somewhat confusing at first sight. It shows that one inch on the map is equivalent to a quarter-mile on the ground; therefore, four inches on the map is equal to one mile on the ground. That is how the R. F. would be shown on a large scale map.

R. F. 1/12,672. 5″ = 1 mile.
R. F. 1/5,280. 12″ = 1 mile.
R. F. 1/253,440. 1″ = 4 miles or a quarter-inch on the map equals 1 mile on ground.

The Metric System, when used, is applied in the same manner. (Figure 2.)

R. F. 1/100,000. Denotes $\dfrac{\text{1 centimeter on map}}{\text{100,000 c.m. on ground}}$

R. F. 1/50,000. 2 c.m. = 1 km.
R. F. 1/100,000. 1 c.m. = 1 km.
R. F. 1/200,000. 1 c.m. = 2 km.

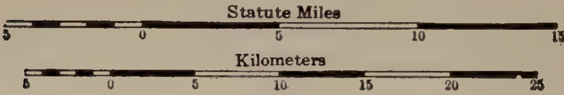
Metric Table and Conversion of Measure:

10 Millimeters (m.n.) = 1 centimeter.
100 Centimeters (c.m.) = 1 meter.
1000 Meters (m.) = 1 kilometer (km.).
25.4 m.m. = 1 inch.
2.54 c.m. = 1 inch.
1 c.m. = 0.4 inch.
1 Meter = 39.37 inches.
1 Meter = 3¼ feet.

1 Meter = 1 yard 3 inches.
1 Kilometer = 1,100 yards.
1 Kilometer = 0.6 miles.
1⅔ Kilometers = 1 mile.

These figures are approximate, but sufficiently accurate for all practical purposes.

SCALE 1:443,500
1 Inch = 7 Statute Miles
1 Centimeter = 4.4 Kilometers



(FIGURE 2.) Scale on Maps.

UNITS OF LINEAR MEASURE.

The following units of Linear Measure are in common use:

Statute Mile. An arbitrary length which is adopted as standard in the U. S. A. and the British Empire. It equals 5,280 feet. Abreviation: m.

Nautical Mile. Average length of a minute of Latitude measured on any Meridian. It equals 6,080 feet. Symbol: (′).

Cable. One-tenth of a Nautical Mile. Its length is generally taken as 600 feet.

Fathom. Equals six feet. Depths on charts are often expressed in terms of this unit.

Kilometers. The average length of one ten thousandth part of a quadrant of a Meridian. Its approximate length is 3,280 feet. Abbreviation: km.

The following is worth memorizing:

6080 : 5280 as 76 : 66
5280 : 3280 as 66 : 41

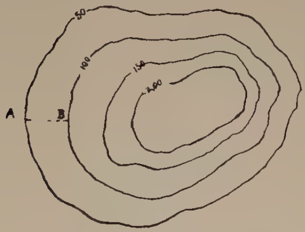
thus:

66 Nautical Miles = 76 Statute Miles.
41 Statute Miles = 66 Kilometers.
41 Nautical Miles = 76 Kilometers.
5 Miles = 8 Kilometers.

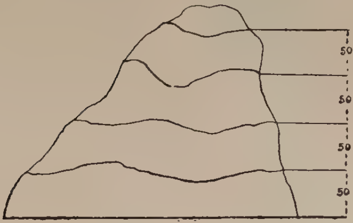
RELIEF: HILLS AND VALLEYS.

The study of relief or hill features is very essential. The various methods by which hill features can be shown are:

a. Contours and Form lines.
b. Hachures.
c. Hill shading.
d. Layer tints.
e. Spot heights.



(FIGURE 3.) Contours.



(FIGURE 4.) Slope.

The contour may be described as a line running along the surface of the ground at the same height above sea level throughout its length. Form lines are approximate contours, drawn in by eye, and are not to be relied upon for accurate information.

The difference in altitude between two successive contours is called the **vertical interval.** The interval used depends on the scale of the map. Contours undoubtedly constitute the most accurate method of showing hill features. The exact

gradient of a slope may be obtained by measuring the distance in plan (the **horizontal equivalent**) between two adjacent. Thus, suppose the V.I. were 200 feet and the H.E. 1,800 feet, the gradient is 200/1800, or 1/9.

The comparative steepness of a hill can be readily gauged by remembering that the contours lie more closely together on the steeper slopes.

The Contour Lines as they appear on a map are shown in Figure 3. The distance from A to B gives the map distance (according to the scale of the map) or Horizontal Equivalent. The figures represent the height in feet, of each contour line above sea level. There is a difference in altitude of 50 ft. between each adjacent contour.

In Figure 4 the hill feature is represented as it would appear on the ground and divided into equal sections for transferring to the map, as in Fgure 3. The Vertical Interval is clearly illustrated and is constant throughout the map. It will be noticed that one side of the hill is much steeper than the other. (Figure 4.) The Vertical Interval is shown as 50 feet, and by the scale of the map the Horizontal Equivalent A to B is 300 ft.

V. I. 50 ft., H. E. 300 ft., Gradient is 50/300, or 1/6.

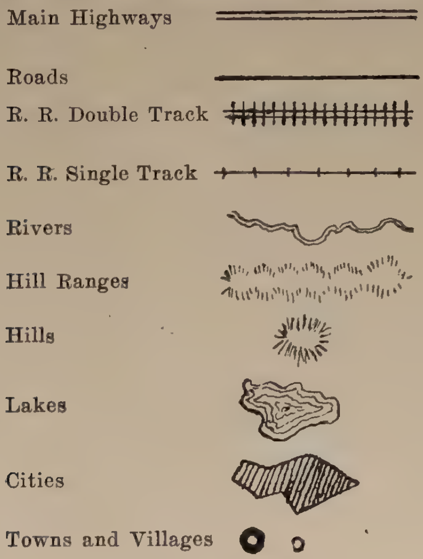
Hachures are lines drawn down the direction of the steepest slope. They give a good general idea as to the shape of the ground, but very little positive and detailed information.

Shading is in principle similar to hachuring: The same effect is produced in the one case by line work and in the other by the use of color.

The system showing relief by **layer tints** is a generally satisfactory method. The system consists in coloring the repetition of the ground between contours by tints which vary according to level. When differences in level are considerable, a layered map is very easily read, since the relief stands out as on a model. A disadvantage is that minor variations of feature cannot be shown.

Spot heights are definite points shown on a map with the exact height above sea level printed against them. On hachured or shaded maps they give only the exact information as to level which the maps contain. For showing minor relief features between contours spot heights are very useful. The **datum line** above which all heights are measured is the mean sea level.

CONVENTIONAL SIGNS AND LETTERING.



(FIGURE 5.) Legend.

Conventional signs for various features of importance on maps are used so that the necessary information may be given without over-crowding the map. The meaning of the various signs is generally obvious. Lists of the conventional signs with their meanings are usually printed in the map margins. This is known as the Legend of the map. The lettering on maps is not chosen haphazard. A particular style is used for the names of features of the same class. (Figure 5.)

Before starting on a cross-country flight, maps of the country over which the pilot intends to fly should be obtained and arranged in the order in which they are intended to be used. The desired track between the point of departure and the objective should be set out on the map. As this is the track to be made good, the features of the ground between the two points, such as railways, rivers, lakes, woods, towns, main roads, etc., should be examined carefully.

Altimeter. Another point which must not be overlooked—and a very important one in hilly countries—is that the altimeter will show the height of the airplane above the point of departure and not necessarily above the point of arrival, or above the various places on the route. The pilot should, therefore, calculate the height at which he must fly in order to clear, with a safe margin, any hills that may be directly in his path. Also, before leaving the ground, the estimated time of passing over various prominent landmarks on the course should be noted so that, when flying, the compass course can be checked by referring to these objects and observing if the actual course made good brings the airplane over them at the estimated times. Should the pilot meet with fog or low clouds and have to fly by compass alone, he will have sufficient data to be able to fix his course by D.R. quite accurately.

Given favorable weather conditions a pilot has no difficulty in steering an absolutely accurate course by use of his map alone.

PLOTTING A COURSE.

In plotting a course, either on a map or on a chart, three drawing instruments are necessary:

The Protractor—a graduated semi-circular or circular instrument. Made of celluloid or brass, it is used for measuring angles of bearings from one point to another, on maps or charts. It is graduated in degrees from 0 to 180 or 0 to 360.

Ruler and pencil for drawing lines joining one point to another and measuring distances.

Dividers—compasses—for measuring distances on the map or chart, and describing arcs of circles.

All bearings are measured clockwise, i.e., from North through E.S.W. This gives a fixed line from which the angle of direction is always measured from one point to another. The angle thus obtained is called the Bearing. The Line is the Meridian of the place running True North and South.

To lay off a Bearing, draw a line from the Starting Point to the desired destination. Then, place the protractor with the center mark over the starting point, taking care that the North and South Line of the Protractor is parallel to the TRUE NORTH and SOUTH LINE on the map, read off the degree immediately over the pencil line and that will give TRUE bearing. (Figure 7.)

Having measured the bearing, it is now necessary to find out the distance between the two points. Take a pair of dividers, place one point on the starting place and the other on the destination. Transfer the Dividers to the Graduated Scale on the map and read off the scale of measurement between the two points.

Orienting a map is placing the map so that the North Line on the sheet points North—TRUE NORTH.

A mistake frequently made is that of setting the map with the True North Line pointing to Magnetic North and vice versa, an error due to the fact that the compass North is the Magnetic North and the map being oriented with the compass.

Some maps may not have a North Line marked on them. In this case the top of the map is generally the North side, i.e., the sides of the map run parallel to the True North. This must not be taken for granted, however, as this is not a hard and fast rule. The map must be checked by some means or other first.

The two most important points are:

1. The True North Line on the map coincides with the True North of the Earth.
2. When setting a map with the Compass the Magnetic North is being used.

After the True Bearing has been obtained **several corrections** have to be made before the Compass Course has been determined. These are for variation, deviation, and Drift if a side wind is blowing. These corrections, however, are dealt with later on.

N. B. A Meridian is any Line drawn True North or South through a place. On a globe or Sphere it is represented by a Great Circle. A map being a flat surface, it is represented by straight lines.

The scale of distance on the map is applicable to any part of that map.

Bearings are measured by the angle made with the Meridian of the place, i.e., a straight line drawn through it running True North and South. The Lines or Meridians printed on the map are not invariably parallel to the side of the map, but they always run True North and South. The Lines cutting the Meridians at right angles run East and West, and are called Parallels of Latitude. Bearing angles are not measured from these lines.

Bearings. Examples of: A. B. is a line running True North and South. C. is a place on that line representing the point of departure. Therefore, A. B. is the Meridian of the place C.

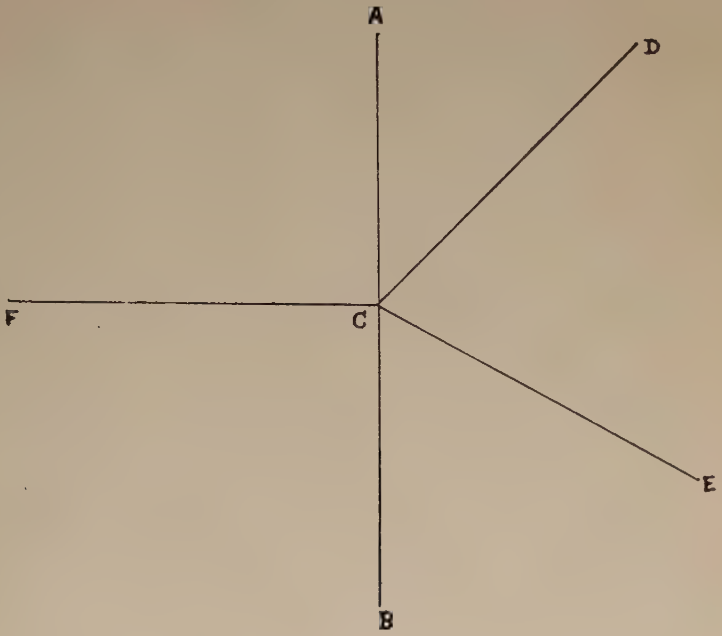
To find the bearings from C to D, C to E, C to F, join each point, and with the center of the protractor at the point C read off the bearings. (Figure 6.)

From C to D the Bearing is 45°.
From C to E the Bearing is 120°.
From C to F the Bearing is 270°.

Bearings and Distances. The Scale of Map—R.F. 1/2, 534400, i. e., 40 miles to 1 inch. (Figure 7.)

Find the bearings and distances from:

1. Dayton to Newton.
2. Dayton to Waterville.
3. Dayton to Austin.

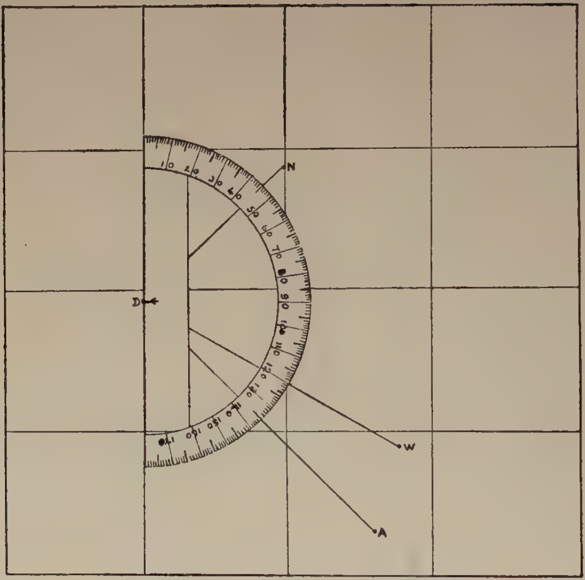


(FIGURE 6.) Bearings.

The bearings and distances read as follows:

1. 45°, 80 miles distant, i.e., 2 inches on ruler.
2. 120°, 120 miles distant, i.e., 3 inches on ruler.
3. 135°, 95 miles distant, i.e., 2 inches and three-eighths on ruler.

When measuring a bearing, with a semi-circular protractor West of 180° South, add 180° to the bearing read off.



(FIGURE 7.) The Protractor.

For example: the bearing from Dayton to Sioux City reads 45° on the protractor. It is West of South, therefore the bearing is 180° + 45° = 225°.

Bearing from Dayton to Sioux City = 225°.

N. B. Figure 7 has been reduced to exactly half size.

CHAPTER II.

CHARTS:

A Chart is a representation of **a portion of the surface** of the globe showing a much larger proportion of water to land, and is adapted to the requirements of the mariner, but with the great advance in aerial navigation, and the long distances now covered across sea and land, it is very essential that pilots be thoroughly acquainted with their use.

The majority of charts used for Navigation are on Mercator's Projection, all Meridians being drawn as straight lines at **right angles** to the **parallels of latitude**, which are also shown as parallel straight lines.

Positions on a chart are fixed by reference to the latitude and longitude, and surface measurement is made in degrees of latitude, each degree containing 60′ of arc, one minute of arc being equal to 6,080 feet or one nautical mile or knot.

The length of 1° of longitude in latitude of 0°, that is on the Equator, is approximately 60 nautical miles, and at the poles latitude 90° it is nothing.

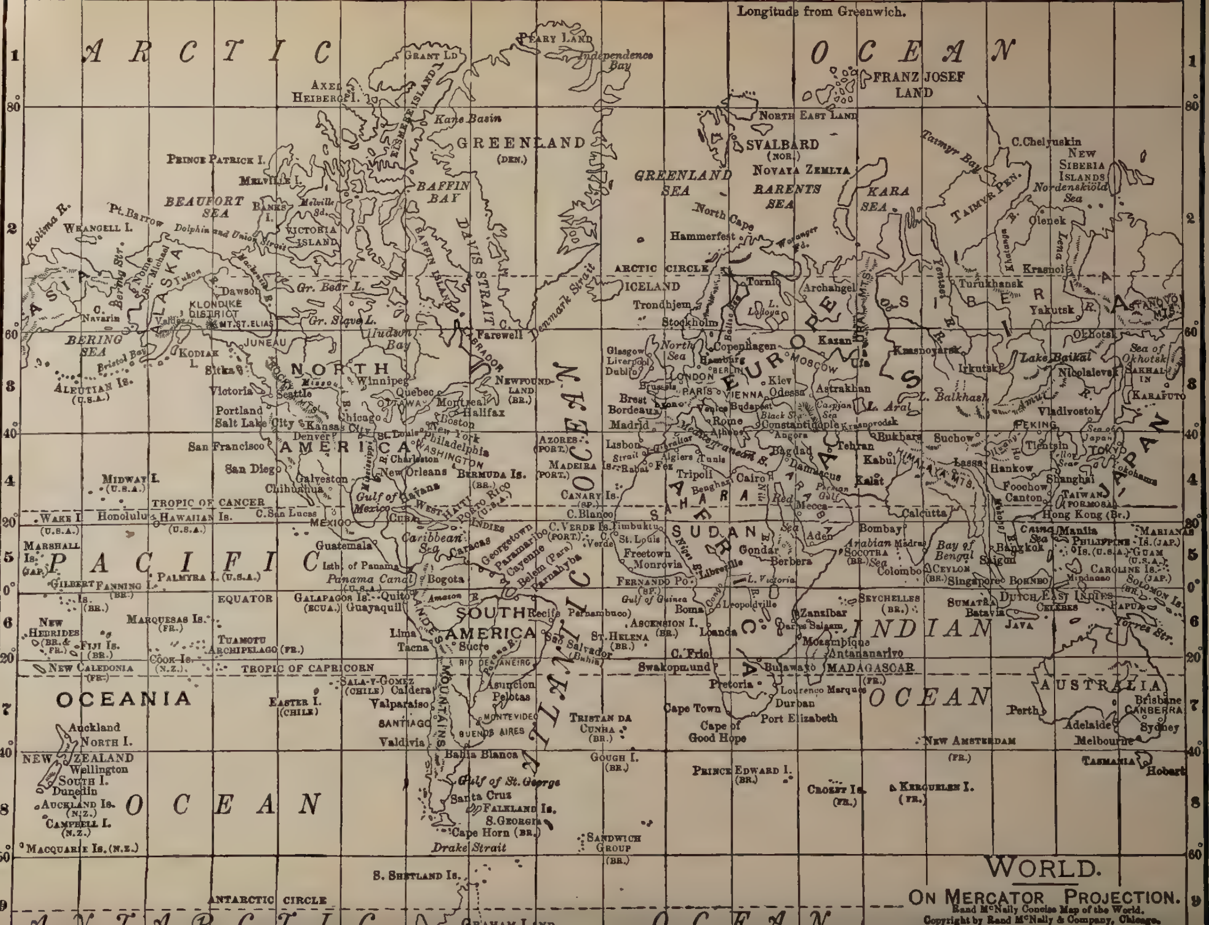
In latitude 60° the length of 1° of Longitude is 30 nautical miles. Degrees of Longitude are therefore useless as a means of expressing distance, and the scale of latitude must always be used.

Scale. Every chart has two scales—

1. A varying one for latitude and distance.
2. A constant one for longitude.

The scale for latitude and distance will be found on the sides of the chart, and the scale of longitude at the top and bottom.

To find distance on a chart, measure with the dividers the distance between the two places, and transfer this distance to the Graduations at the side of the chart as nearly opposite the places as possible. It is very important that the distance should



WORLD.

ON MERCATOR PROJECTION.

Rand McNally Concise Map of the World.

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be measured opposite the two places, since **as the scale of latitude is increasing towards the pole,** distances measured to the North or South of the two places will be incorrect. (Figure 10.) If the places have the same or nearly the same latitude, take half the space between them and apply it to the graduated Meridian above and below the parallel on which the places are situated. The difference between the degrees of the extreme points converted to minutes will be the distances required in nautical miles. If the distance between the two points is great, take off with the dividers a distance equal to, say 30′ of latitude at the mid-latitude of the two points, and lay this off on the line joining the two points.

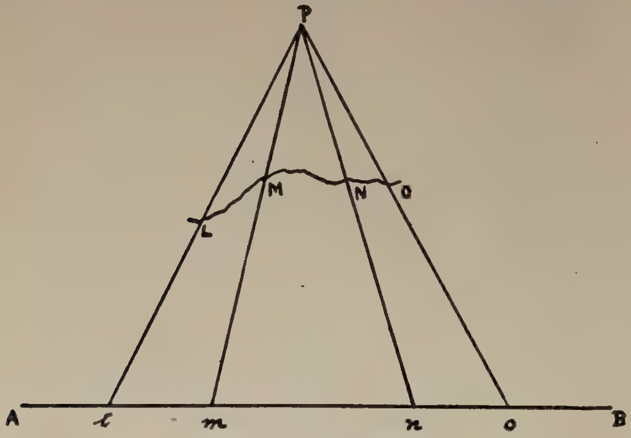
Latitude and Longitude can be laid off on a chart with a parallel ruler, or protractor.

The key to the chart is the **note or legend** and should be read carefully.

The coast line, channels and river mouths are indicated by light-houses, light-ships or buoys, each with their own characteristic marking and light, and are of great assistance when flying over sea or along the coast. Especially at night is this the case, the lights enabling the pilot to check his course from time to time.

Projections. A projection is literally the figures obtained on any surface AB, by joining the point of projection, P, to all the points on the figure to be projected and constructing these lines to meet the surface. (Figure 8.) Thus *l, m, n,* and *o* are the projections on AB of the points l, m, n, and o from the point of projection P. There are, however, natural and artificial projections, and some of the so-called projections are not strictly projections, but representations of the earth's surface on a conventional system.

Mercator Projection. This is an artificial projection in which the **Meridians** are parallel straight lines **equi-distant** from each other. The parallels of latitude are perpendicular to the Meridians at such distance from each other, increasing from the Equator, that the measures of a Degree of Longitude and Latitude at any point of the projection shall have the same ratio as between their measures on the surface of the Sphere at the corresponding point. Its useful property is that a straight line makes a constant angle with the Meridians. Distances can be measured by the scale of latitude. **The straight line,** however, does not represent the shortest distance between points on it, except when the line runs North and South, along the Equator.



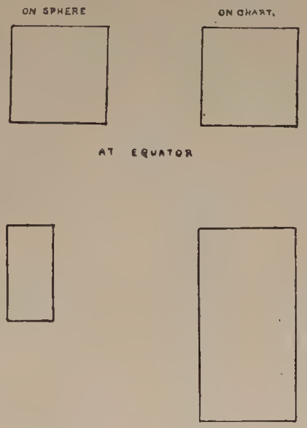
(FIGURE 8.) Projections.

Correction for Distortion. On the Sphere the length of 1° of Longitude is 60 Nautical miles at the Equator and Zero at the Poles.

On a Mercator's Chart, however, since the Meridians are parallel, the length of a degree of Longitude is the same in any Latitude. Thus, suppose a chart were constructed to a scale of 3 inches to 1° of Longitude at the Equator, a degree would also measure 3 inches in Latitude 60° (or in any other

Latitude), although in Latitude 60° on the Sphere, a degree of Longitude is actually exactly half as long as at the Equator.

In order to preserve the correct shape of portions of the Earth's surface, the scale of Latitude is increased in the same proportion as the scale of Longitude. It follows, therefore, no uniform scale of distance is possible on a Mercator's Chart, and areas are exaggerated in High Latitudes.

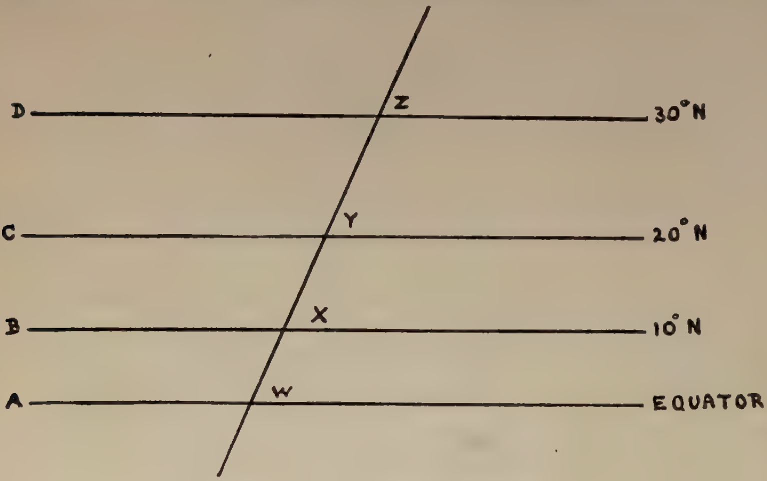


(FIGURE 9.) Relative sizes.

In Figure 9 the relative sizes of areas enclosed by 1° of Latitude and 1° of Longitude on the Earth, and as represented on a Mercator's Chart, are compared at the Equator and in Latitude 60° N.

Measurement of Distance. The length of a Rhumb Line between two places on a Mercator's Chart is always referred to as the distance. As the latitude increases, parallels of latitude become wider apart. By taking a Mercator Chart and measuring the length representing the difference of latitude at the bottom and doing the same at the top of the latitude scale, it is at once apparent. (Figure 10.)

ABCD represents parallels of latitude on a chart and WXYZ a Rhumb Line. It is plainly seen that the whole distance WZ cannot be measured accurately by taking WX and applying it as the latitude scale between A and B or C and D. The distance WX would be measured on the scale between A and B, the distance between X and Y on the scale, B and C and so on.



(FIGURE 10.) Latitude Differences.

Construction of a Mercator's Chart. This is an artificial projection in which the Meridians (Great Circles) and the Parallels of Latitudes (Small Circles) are straight lines cutting one another at right angles.

Meridional Parts for any Parallel of Latitude are the number of minutes of Longitude measured on a Meridian from the Equator to that parallel of latitude on a Mercator's Chart.

In the construction of a Mercator's Chart a table of Meridional Parts is required. (Table 1.)

On the Sphere, Latitude 53° would be 3180 miles from the Equator, North or South, $53° \times 60' = 3180'$ (miles). On a Mercator's Chart, due to distortion, this is not the case; therefore, reference must be made to the table of Meridional Parts, from which it is seen Latitude 53° is distant 3745.1 miles from the Equator, and it would be drawn to scale on the chart to correspond with that distance.

Example: Construct a Mercator's Chart between the Parallels of 53° and 57° and 3° and 7° Longitude on a scale of 2″ to one degree of Longitude.

The length of a degree of Latitude in inches equals the difference between its Meridional Parts multiplied by the scale of Longitude and divided by 60′.

Latitude	**Meridional Parts**
53°	3745.1
54°	3845.7
55°	3948.8
56°	4054.5
57°	4163.0

$$\begin{array}{lr} \text{Lat. }53^\circ\text{:} & 3745.1\\ \text{Lat. }54^\circ\text{:} & 3845.7\\ \hline & 100.6\\ & 2\\ 60 \,| & 201.2\\ \hline & 3.353 \end{array} \qquad \begin{array}{lr} \text{Lat. }54^\circ\text{:} & 3845.7\\ \text{Lat. }55^\circ\text{:} & 3948.8\\ \hline & 103.1\\ & 2\\ 60 \,| & 206.2\\ \hline & 3.436 \end{array} \qquad \begin{array}{lr} \text{Lat. }55^\circ\text{:} & 3948.8\\ \text{Lat. }56^\circ\text{:} & 4054.5\\ \hline & 105.7\\ & 2\\ 60 \,| & 211.4\\ \hline & 3.525 \end{array}$$

$$\begin{array}{lr} \text{Lat. }56^\circ\text{:} & 4054.5\\ \text{Lat. }57^\circ\text{:} & 4163.0\\ \hline & 108.5\\ & 2\\ 60 \,| & 217.0\\ \hline & 3.617 \end{array}$$

Draw a horizontal line to scale representing 2″ to a degree, i.e., 8″ in length. (Figure 11.)

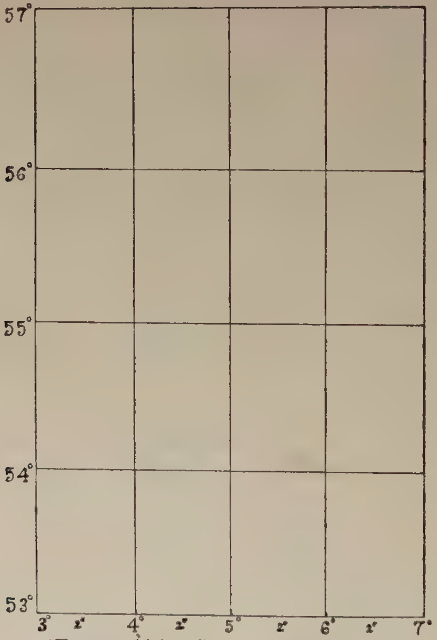
From 3° of Longitude draw a perpendicular line divided into degrees of Latitude distant from one another:

$$\left.\begin{array}{l}\text{Lat. }53^\circ\\ \text{Lat. }54^\circ\end{array}\right\}\text{ 3.353 inches.} \qquad \left.\begin{array}{l}\text{Lat. }55^\circ\\ \text{Lat. }56^\circ\end{array}\right\}\text{ 3.525 inches.}$$

$$\left.\begin{array}{l}\text{Lat. }54^\circ\\ \text{Lat. }55^\circ\end{array}\right\}\text{ 3.436 inches.} \qquad \left.\begin{array}{l}\text{Lat. }56^\circ\\ \text{Lat. }57^\circ\end{array}\right\}\text{ 3.617inches.}$$

Complete the square and draw in Parallels of Latitude and Longitude.

The diagram is representative and not drawn to size in accordance with above calculations. 3.353 inches would be the distance along the perpendicular line from 53° to 54°, and the distances between the various degrees are obtained similarly.



(FIGURE 11.) Chart Construction.

Some charts are constructed on the **Gnomonic Projection,** but these are not commonly used for Air Navigation. The special feature of the Gnomonic Projection is that it shows all arcs of Great Circles on the Sphere as straight lines on the chart. A Gnomonic Chart is of use in long distance navigation because it allows the shortest distance between two points to be laid down at once by a straight line, but apart from this, it has practically no useful features—bearings, shapes and areas are all distorted.

A Polyconic Projection is a natural projection, in which the points on the surface of the Sphere are projected from the center onto a cone which has for a base a parallel of latitude, and its vertex in the point where a tangent to the parallel intersects the Earth's axis. The degrees on this parallel preserve their true North, and the general distortion of the figure is less than in any other projection. It has many disadvantages, however, which do not recommend it for use in navigation, although it is useful for general purposes. There are many modifications of the projection which are all more or less identical in principle.

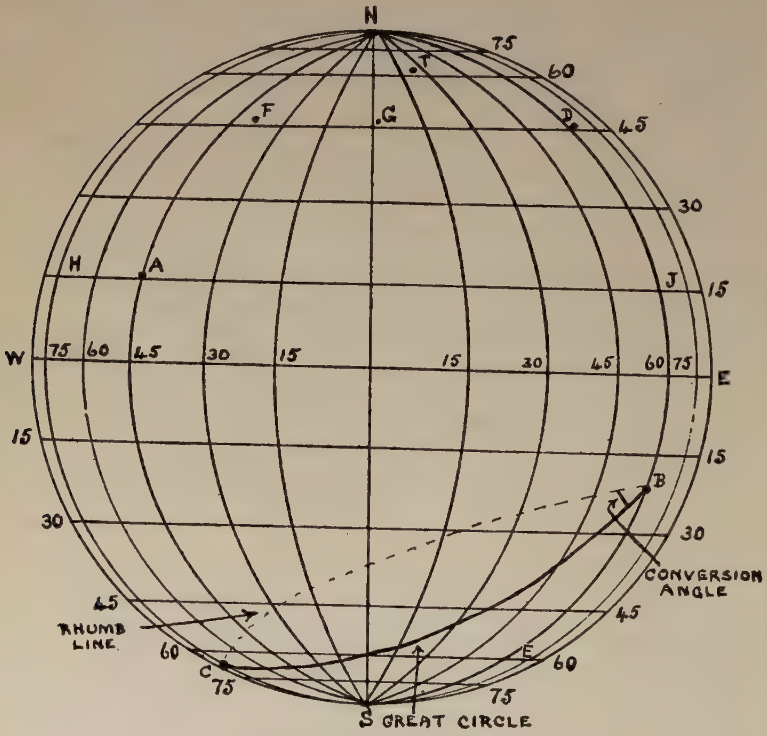
PLOTTING A COURSE.

Great Circle flying is navigating the airplane across the sea or vast stretches of territory from one point to another, so that the track lies on the **arc of a Great Circle.** The difficulty of this is, that the shortest distance between any two places, except on the Equator or on a Meridian, makes different angles with each Meridian it crosses. It is necessary, however, in order to keep the airplane on the Great Circle track to change the course constantly. To do this the longitude and latitude of a number of points on the Great Circle are plotted out and then the course is flown from point to point.

As the shortest distance between two points on a plane surface is the straight line joining them, so the shortest distance between two points on the surface of a sphere is the shorter arc of the Great Circle intercepted by the points. In Figure 12 the black line passing through points B and C represents the arc of a Great Circle, so that in flying from B to C the shortest possible route would be taken by the airplane following this line. It should be carefully observed, however, that the Great Circle cannot be followed by flying on a constant course. Thus, at the departure point the course is about 210°, but this changes to 300°. (Figure 12.)

> "Accordingly, it would be necessary to alter course frequently in order to fly along a Great Circle track."

Rhumb Line Flying. Consider next the dotted line passing through points B and C. (Figure 12.) This cuts every Meridian it meets at the same angle (240°) and represents the Rhumb Line through the points. It will be seen that a Rhumb Line is a spiral about the pole. It is evident, therefore, the



(FIGURE 12.) The Sphere.

path along the Rhumb Line is not the shortest distance between the two points, but it offers a great advantage in that the

> "Rhumb Line joining two places may be followed by maintaining a constant True Course."

It remains to be decided whether Great Circle Distance or Rhumb Line Distance should be adopted for flights of average length.

Consider the following comparisons:

	Rhumb Line	**Great Cir. Flying**
Paris-New York......	3,088 Naut. Miles	2,976 Naut. Miles
Tokio-Paris	6,182 Naut. Miles	5,219 Naut. Miles

It is seen that in the former case 3½ per cent. of the Rhumb Line distance is saved by following the Great Circle, and in the latter about 15½ per cent. As an alternative, suppose it were required to fly from a place on the West Coast to a point 500 miles away to the East on the same parallel of Latitude. The initial course set to fly on a Great Circle would be 83° True; this course would have to be changed 1° for 35 miles, until the final course was 97° True. The Rhumb Line track would be along the parallel and the course steered 90° True for the whole journey.

The saving in distance would be less than a mile. Thus, for flights within a range of present day airplanes the difference between Great Circle distance and Rhumb Line distance is negligible.

> There is no question that the Rhumb Line track is greatly to be preferred to the Great Circle track for all ordinary purposes in flying.

Bearings on Charts. Rhumb Line bearings are given absolutely accurately on Mercator's Charts. The graduated circles which are printed on charts make it a simple matter to lay down or take off a bearing, either True or Magnetic. The circle is called a "Compass Rose." This consists of two concentric circles, the outer one indicating True North, the inner one Magnetic North and degrees from Magnetic North. The outer is graduated from 0° to 360° clockwise.

The inner circle giving magnetic bearings is graduated in degrees from 0° to 90° East and West from North and South. Thus, a bearing of 160° is named S 20° E. This method is not used in aerial navigation with the exception of Naval craft.

The variation in the region represented on the chart is given on the compass rose with the annual rate of change. Bearings can be conveniently laid down or taken off from the compass rose by means of the parallel rulers or the protractor; they should always be referred to the nearest "Compass."

As all Meridians are parallel straight lines, True Bearings may alternatively be referred to a Meridian by means of a protractor.

Before using a chart, examine the title carefully. All conventional signs for use on the chart are shown there. The date of the edition of the chart is on the South margin.

If the **North or South line of the compass** on the chart is on or parallel to a Meridian, the chart is a True one, otherwise it is a Magnetic Chart.

The Meridians mark the Longitude of any place reckoned from Greenwich, which is Longitude 0°. If then, with a chart before you, the numerical value of the Meridians increase to the right, the Longitude is East; if to the left, the Longitude is West. When a chart contains the Meridian of 180° the East Longitude to the left of the 180° Meridian will decrease to the left and the West Longitude to the right will decrease to the right.

Left E. 178° 179° 180° 179° 178° W. Right.

CHAPTER III

LATITUDE AND LONGITUDE

The Sphere. The Earth is an oblate spheroid, but for nearly all practical purposes it may be assumed to be a sphere. The position of any point on the surface of the Earth may be defined by the Latitude and Longitude of the point.

Latitude is measured from 0° to 90° N. or S. of the Equator along a Meridian and is expressed in Degrees (°), Minutes (′), and Seconds (″).

Longitude is measured from 0° to 180° E or W of the Prime Meridian along the Equator or in a parallel latitude and is also expressed in degrees, minutes and seconds.

Greenwich is generally accepted as the Prime Meridian, but this is not universal for all countries.

In Figure 12 suppose G represents the position of Greenwich, then WGS is the Prime Meridian. WE is the Equator. The position of the line A is:—Lat. 15° N, Long. 45° W, and the position of the point E is:—Lat. 60° S, Long. 75° E.

Difference of Latitude and Longitude. One position on the Earth's surface is relative to another by the difference of Latitude and difference of Longitude between the places. If an airplane is proceeding from a place F to a place T, the d. Lat. is named N or S according as the parallel of the **destination** is **N** or **S** of the parallel of the point of departure. The d. Long. is named E or W according as the Meridian of the **destination** is **E** or **W** of the Meridian of the departure point.

Suppose that F is in Lat. 45° 30′ N and Long. 40° 20′ W. And T is in Lat. 60° 27′ N and Long. 15° 30′ E. (Figure 12.) Then the difference in Latitude and Longitude is:

Lat. 45°, 30′ N.	Long. 40°, 20′ W.
Lat. 60°, 27′ N.	Long. 15°, 30′ E.
d. Lat. 14°, 57′ N.	Long. 55°, 50′ E.

Longitude, Time and Arc. The sun makes its apparent daily circuit around the earth in 24 hours. Therefore, 24 hours are the equivalent to 360°, and

1 hr. = 15°, 1 min. = 15′, 1 sec. = 15″.

To convert arc into time divide the degrees, minutes and seconds by 15.

Example:—Convert 34°, 16′, 30″ into time.

15/34°, 16′, 30″

= 2 hrs. 17 m. 6 s.

by reversing the above, time may be changed into arc:

Example:—Change 7 hrs. 32 m. 15 s. into Arc.

7 hrs. 32 m. 15 s.
15

113° 3′ 45″

The rules for time and arc may be employed to find:

The difference between Greenwich Time and the time at a place whose longitude is given:—and the longitude corresponding to a given difference of time. Time at a place in E. Longitude is always fast or greater than the time at Greenwich, and at a place in W. Longitude it is always slow or less than Greenwich Time.

For Example:—What is the difference in time between the time at a place 72°, 50′ E. Longitude and time at Greenwich.

15/72°, 50′ E.

= 4 hrs. 51 m. 20 s. Fast G. T.

At a place 124°, 10′, 45″ W.

15/124°, 10′, 45″

= 8 hrs. 16 m. 43 s. Slow G. T.

TABLE OF MERIDIONAL PARTS.

The Table is given in Degrees only. It runs from 1° to 60°.

Degrees	Parts	Degrees	Parts	Degrees	Parts
1.	59.6	21	1280.8	41	2686.2
2.	119.2	22	1344.9	42	2766.0
3.	178.9	23	1409.5	43	2847.1
4.	238.6	24	1474.5	44	2929.5
5.	298.3	25	1540.1	45	3013.4
6.	358.2	26	1606.2	46	3098.7
7.	418.2	27	1672.9	47	3185.6
8.	478.3	28	1740.2	48	3274.1
9.	538.6	29	1808.1	49	3364.4
10.	599.0	30	1876.7	50	3456.5
11.	659.6	31	1946.0	51	3550.6
12.	720.5	32	2016.0	52	3646.7
13.	781.5	33	2086.8	53	3745.1
14.	842.8	34	2158.4	54	3845.7
15.	904.4	35	2230.9	55	3948.8
16.	966.3	36	2304.2	56	4054.5
17.	1028.5	37	2378.5	57	4163.0
18.	1091.0	38	2453.8	58	4274.4
19.	1153.9	39	2530.2	59	4389.1
20.	1217.1	40	2607.6	60	4507.1

TABLE 1.

CHAPTER IV.

MAGNETIC VARIATION, DEVIATION, AND BEARINGS.

MAGNETIC VARIATION.

Isogonic Lines are lines joining places of equal variation.

Agonic Lines are lines joining places where variation is zero or where the compass needle points True North.

The earth is a magnet having the same characteristic properties as any other magnet. The magnetic field of the earth is subject to small changes, both irregular and periodic. The **magnetic poles** of the earth are not coincident with the true poles, one being situated in **Latitude 73° N, Longitude 96° W,** and the other in **Latitude 72° S, Longitude 155° E.** There are certain places on the earth's surface where the direction of the true pole and of the magnetic pole are coincident, but generally the two directions are not identical. The angle between the true meridian and the magnetic meridian is the angle of variation (or declination). At places where the North seeking end of the needle lies **West** of the true meridian, the variation is **Westerly,** and where it lies **East** of the true meridian, the variation is **Easterly.**

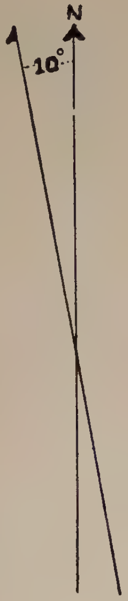
The variation of any given place may be obtained from magnetic charts, but practically every map or chart used in the air gives the variation for the region represented on it. The amount and sine of variation at various parts of the earth is conveniently shown on some maps and charts by lines joining places at which variation has the same value; these are called **Isogonals.**

The Agonic line is the line of no variation, i. e., it joins points on the earth's surface at which true North and Magnetic North are coincident. The magnetic chart shows that variation has widely different values at different places. In addition to this, the value of variation changes slowly and fairly regularly at any given place; this change in the earth's magnetic field is of considerable importance. These changes can be explained by imagining that the magnetic pole describes a path about the true pole in the direction of E.S.W. in the course of about 960 years.

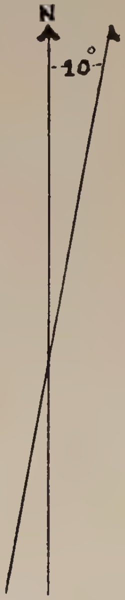
The annual change in variation is given on most maps and charts.

The application of variation when converting True Bearings to Magnetic Bearings and vice versa is as follows:

Magnetic to True:—Add East Variation.
Sub. West Variation.
True to Magnetic:—Add West Variation.
Sub. East Variation.



(FIGURE 13.)



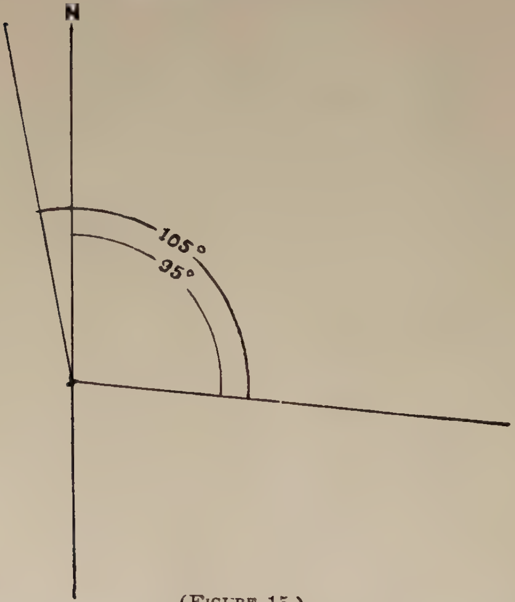
(FIGURE 14.)

The True North is represented on the map by an arrow, and the Magnetic North by a similar arrow cutting it at an angle in the direction East or West according to the Magnetic Variation of the area covered by that particular map. Two examples are given showing Easterly and Westerly Variation.

In Figure 13 the variation is 10° W.
In Figure 14 the variation is 10° E.

Converting True Course to Magnetic Course: The True Course is 95°, Variation 10° W. What is the Magnetic Course? (Figure 15.)

True Course	95°
Variation	+ 10° W.
Magnetic Course	105°



(FIGURE 15.)

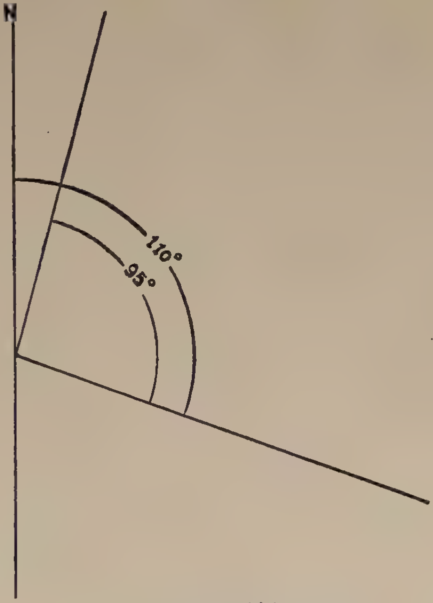
The True Course is 110°, Variation 15° E. What is the Magnetic Course? (Figure 16.)

True Course	110°
Variation	— 15° E.
Magnetic Course	95°

The True Course is 275°, Variation 10 W. What is the Magnetic Course?

True Course	275°
Variation	+ 10° W.
Magnetic Course	285°

The True Course is 315°, Variation 15° E. What is the Magnetic Course?



(Figure 16.)

True Course	315°
Variation	—15°
Magnetic Course	300°

Correcting Magnetic Course to True Course: The Magnetic Course is 70°, Variation 10° W. What is the True Course?

Magnetic Course	70°
Variation	—10° W.
True Course	60°

The Magnetic Course is 240°, Variation 15° E. What is the True Course?

Magnetic Course	240°
Variation	+ 15°
True Course	255°

It is very evident from the examples that the application of Variation is a simple problem; similarly, the correction of a Magnetic Bearing to a True Bearing will present no difficulty if the formula be adhered to. Practice and common sense are the essential requirements.

Deviation. The rules for converting magnetic course to compass course and vice versa are very similar to those already given for the application of variation.

Magnetic to Compass—Add Westerly Deviation
Sub. Easterly Deviation

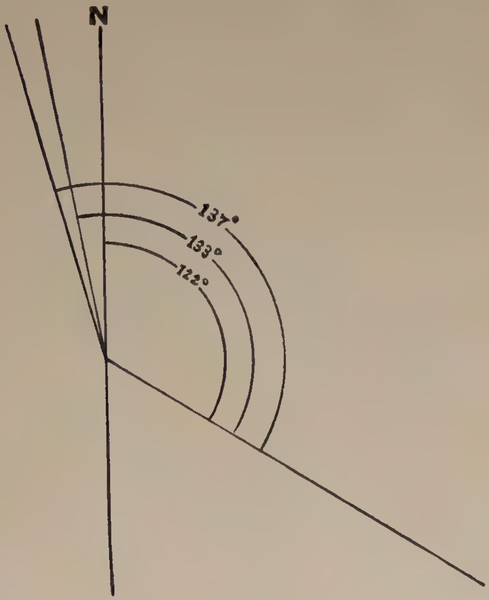
Compass to Magnetic—Add Easterly Deviation
Sub. Westerly Deviation

Deviation is named Easterly (or +) if the North seeking end of the needle is deflected Eastward of the Magnetic Meridian, and Westerly or—if the deflection is Westerly. The amount of deviation is determined by swinging the compass. If the compass readings be found the same as the magnetic course, there is naturally no deviation on that particular point.

Deviation is always calculated **from Magnetic North** just as variation is calculated from True North.

If the deviation be **Westerly** its effect is to **increase** Magnetic Course by the amount of the deviation. If Easterly the effect is the reverse.

Examples: True Course 122°, variation 15° W, deviation 4° E. Find compass course. (Figure 17.)



(FIGURE 17.)

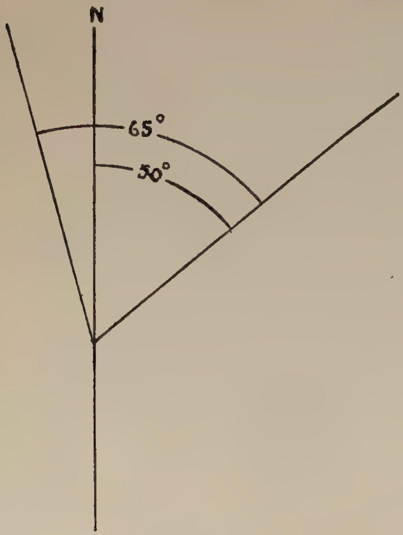
True Course	122°
Variation	+ 15°
Magnetic Course	137°
Deviation	— 4°

133° Compass Course.

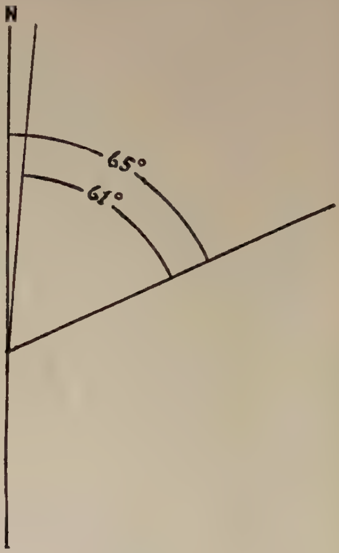
Compass reading is 10°, variation 15° W, dev. 5° E. What is the True Course?

Compass Course	10°
Deviation	+ 5°
Magnetic Course	15°
Variation	—15° W.
	0° or 360° N.

True Course 50°, Magnetic 65°, Compass Course 61°. Find variation and deviation. (Figures 18 and 19.)



(FIGURE 18.)



(FIGURE 19.)

Magnetic Course	65°
True Course	50°
Variation	15° W.

Magnetic Course	65°
Compass Course	61°
Deviation	— 4 E.

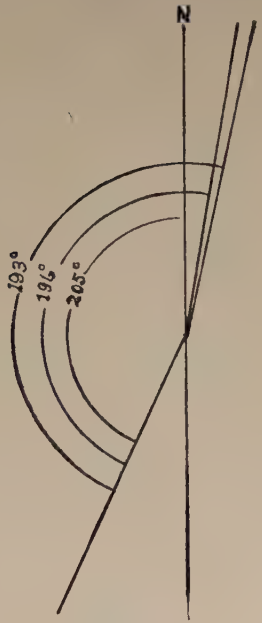
Variation	15 West
Deviation	— 4 East

Find course to steer by compass to make good a course 205° T, variation 12° E, deviation 3° W. (Figure 20.)

205° T.
— 12° E. Variation

193° Magnetic
+ 3° W. Deviation

196° Compass Course.



(FIGURE 20.)

What is the True Course corresponding to a compass course of 198°, Variation 18° W, Deviation 3° W?

198° Compass Course
— 3° W. Deviation

195° Magnetic Course
— 18° W. Variation

177° True Course

N. B. When reading off the angles, care must be taken that the zero mark on the protractor is placed on the:
True North Line for True Course.
Variation Line for Magnetic Course.
Deviation Line for Compass Course.

The bearing of an object was 40° by a bearing compass when the course of the airplane was 170° by that compass. True Bearing to object 60°; variation 10° E. Find the deviation of the pilot's compass by which the course was 185° at the same instant.

True Bearing of object	60°
Variation	10° E.
Magnetic bearing of object	50°
Bearing by compass	40°
Deviation on course 170° in bearing compass	10° E.
Magnetic course of airplane at that instant —(170° + 10°)	180°
Course by pilot's compass	185°
Deviation by pilot's compass	5° W.

Interpolation. It is often very necessary to obtain the deviation for a course other than the eight recorded. This may be done by interpolation, i. e., to find the compass course corresponding to a magnetic course 108°; the deviation on 90° M. is + 5° and on 135° M. is + 2°; then the deviation decreases 3° through a change of course of 45°, i. e. 1° through a change of 15°. (Figure 22.) Now the change from 90° to 108° is 18°, so that it may be taken that from 90° M. the decrease in deviation will be 1°; therefore, the deviation on a course of 108° is + 4° and the compass course is 104. These calculations are very simple and no difficulty should be experienced in taking out a deviation for any course correct to the nearest degree.

Deviations are shown as in Figure 22.

Deviation Cards. Figure 21 gives an example of a Deviation Card showing a complete record of the deviations.

Figure 22 shows the compass course to steer. This is quite sufficient and less confusing, but a complete record of the deviations on the different points must be kept.

Magnetic	**Compass**	**Deviation**
0° (360°)	348°	12° E.
38°	39°	1° W.
263°	278°	15° W.
309°	296°	13° E.

(FIGURE 21.) Deviation Card.

For Magnetic Course	**Steer by Compass**
N. 0°	358°
N. E. 45°	41°
E. 90°	85°
S. E. 135°	133°
S. 180°	183°
S. W. 225°	229°
W. 270°	273°
N. W. 315°	315°

(FIGURE 22.) Deviation Card.

The first four readings show + or Easterly deviation, the next three — or Westerly deviation, and the last reading the Compass reading and the magnetic course are the same.

Deviation Alters as the Course of an Airplane is Changed. It is extremely important to remember this when bearings are taken by bearing compass. For example: suppose that the compass bearing of an object were 270°, the course of the airplane being 160°, and it is required to find the magnetic bearing of the object. Deviations are shown as in Figure 22. For the sake of clearness the interpolation is worked out fully.

Deviation on 135° M.................. + 2°
Deviation on 180° M.................. — 3°
Change in deviation between
135° M. and 180° M. (45°)........... = 5°
Change in course between
135°M and 160° M. .... =25°

Change in deviation between
135° M. and 160° M.................25°×5°

45° = 3° nearly

Therefore, deviation on 160° . + 2° — 3° = — 1°
The Magnetic bearing of object..........269°

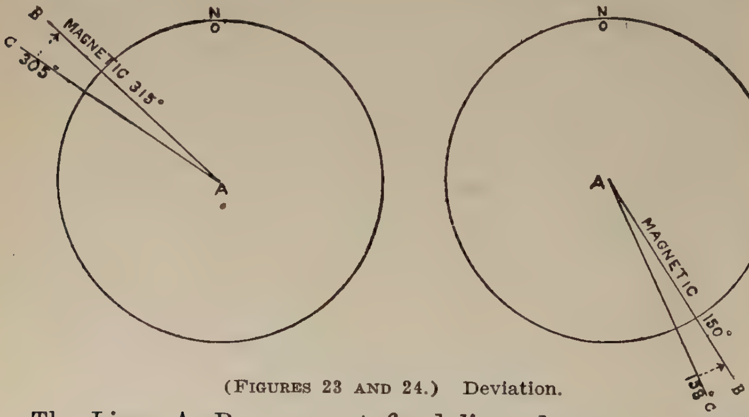
It must be borne in mind that when a bearing is taken by bearing compass, the deviation on the Course of the Airplane at that instant must be applied to it.

PRACTICAL DEMONSTRATION OF DEVIATION.

In Figure 23 the Deviation is Easterly 10°.

In Figure 24 the Deviation is Westerly 8°.

The two circular diagrams each represent the Compass Card revolving on the Axis A.



(Figures 23 and 24.) Deviation.

The Lines A. B. represent fixed lines drawn to a known magnetic point.

N. B.—The Lines A. B. are fixed Lines and the card revolves.

It is desired to steer a course 315°. On checking the compass it is found that when the machine is headed on a point 315° Magnetic it reads 305°, i.e., the Card continues rotating to the East and comes to rest with the 305° under the Line A. B. instead of under the Line A. C. Figure 23.

Therefore, it is plainly evident that some metallic substance on the machine has drawn the compass card around in an Easterly direction and an error of 10° is shown. The Deviation consequently on 315° is 10° E.

In Figure 24 the Magnetic Course is 150°, but although the machine is headed to a known point in this direction, the card continues to revolve to the West until it comes to rest with the 158° under the Line A. B.

The metallic attraction in the plane has pulled the Compass Card back in a Westerly direction and an error of 8° is shown. The Deviation consequently on 150°, is 8° W.

The corrections would read:

Magnetic Bearing	Steer by Compass
150°	158°
315°	305°

BEARINGS.

Bearings. Bearings of distant objects can be taken by means of a compass to which a suitable righting arrangement is fitted. This is described as a **Bearing compass.**

A True Bearing of a place is an angle contained by the True Meridian of the observer and the Great Circle passing through the observer and the place. Bearings are measured in degrees from 0° to 360°, reckoned from North through East, i.e., clockwise.

The Compass Bearing of a place is the angle which the Compass Needle makes with the Great Circle passing through the center of the needle and the place.

Magnetic Bearing of a place is the angle contained by the magnetic meridian of the observer and a great circle passing through the observer and the place.

BACK BEARING OR RECIPROCAL OF A BEARING.

A Back Bearing is a bearing from an observer's position to a distant object expressed as the bearing **from the object** to the observer. It is equal to the forward bearing plus 180°. Thus if the forward bearing from a point A to a point B is 90°, the back bearing between A and B is 90° + 180° = 270°; or if the forward bearing from A to B is 320°, the back bearing or reciprocal is 320° + 180° = 500°, and 500° — 360° = 140°. In this case it is usual to subtract 180° from the forward bearing to obtain the back bearing. Therefore, the following rule applies:

To obtain back bearing between two points, if the forward bearing is **less than 180°** add 180°.

If the forward bearing is **greater than 180° subtract 180°.**

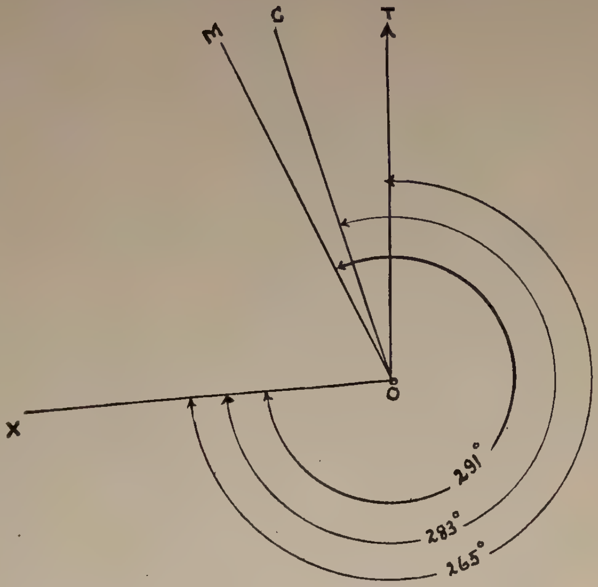
Compass Error. Compass error is the algebraical sum of variation and deviation.

Example:

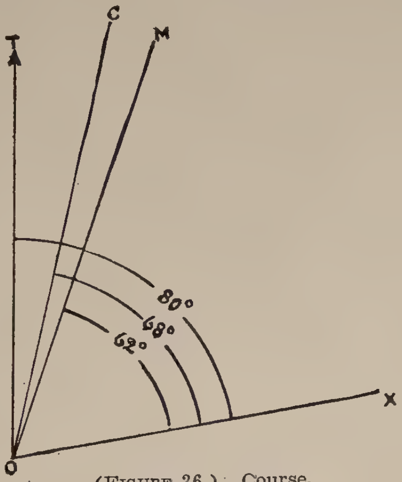
Magnetic Variation	26° W.	Magnetic Variation	18° E.
Deviation	8° E.	Deviation	6° W.
Compass Error	18° W.	Compass Error	12° E.

Figure 25 True Bearing = Angle TOX = 265°
Magnetic Bearing = Angle MOX = 291°
Compass Bearing = Angle COX = 283°
Variation = Angle TOM = 26° W.
Deviation = Angle MOC = 8° E.
Compass Error = Angle TOC = 18° W.

Figure 26 True Course = Angle TOX = 80°
Magnetic Course = Angle MOX = 62°
Compass Course = Angle COX = 68°
Variation = Angle TOM = 18° E.
Deviation = Angle MOC = 6° W.
Compass Error = Angle TOC = 12° E.



(FIGURE 25.) Bearing.



(FIGURE 26.) Course.

CHAPTER V.

DRIFT, DEAD RECKONING, RADIUS OF ACTION

When an airplane is flying in a wind which is blowing at an angle to its course, an element known as "Drift" is introduced.

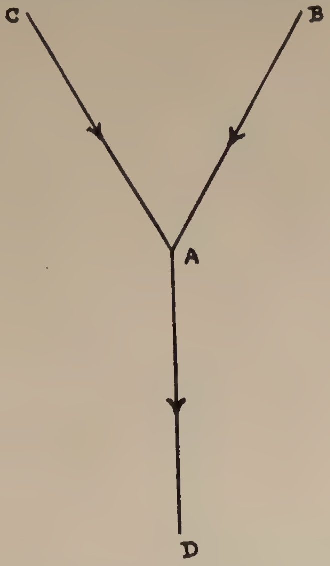
Calculations by Flight. When Meteorological reports are not available, the amount of Drift can be ascertained by flying between two points, and then the track being known, the drift is found by the angle formed between the course and the track.

When the course and track are known, to **find the wind velocity,** fly a given time from the point of departure and then fix your position. A line is then drawn between these two points, the distance worked out, and the difference between the Air Speed and the Ground Speed will determine the velocity of the wind. The desired track by repeated observations can be held with accuracy. A constant check is necessary if the distance from point to point is considerable, as the velocity and direction of the wind varies according to the time of day and the territory flown over. Towards dusk, the wind as a general rule drops, and secondly, the wind direction is considerably affected by the contours of the ground.

Wind Change Correction. For example, the pilot wishes to fly to a place bearing 290° from his point of departure. The wind is on the port side and the pilot is flying sufficiently in the wind to take care of the drift. Steering a course of 275° to make good the desired track he has a drift of 15° to starboard. After flying for some time he checks this and discovers the drift to be actually 25° to starboard, the airplane therefore making good a track 300° which is 10° to starboard too much. The course is immediately changed to 265° and again checked, and showing 25° drift to starboard, it will then be seen the airplane is flying along the desired track. Periodically, according to the conditions, the drift should be checked.

Parallelogram of Velocities. The method employed to calculate the effect of the wind on an airplane in flight is governed by the theory of the parallelogram of velocities, by means of which the wind, the track and the course steered are represented graphically. The parallelogram of velocity depends on the following facts:

1. Any force can be represented in magnitude and direction by a straight line, and any force acting on a body to produce motion can be split up into two or more components.
2. Conversely, any two forces acting together on a body can be compounded into one resultant force.

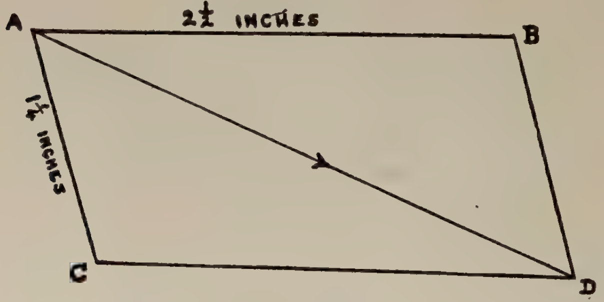


(FIGURE 27.) Forces.

In Figure 27, let A be any body, on which two forces B and C are acting. A will not move in the direction AB nor in the direction AC, but in the resultant direction AD.

The value of this resultant is obtained by the parallelogram of velocities. (Figure 28.)

From any point A, lay off AB, to represent any magnitude and direction the force B acting on the body A. From A, lay off AC, to represent the velocity produced by the force C. Complete the parallelogram ABCD. Then AD represents, in the direction of magnitude, the resultant velocity of the two components AB, AC. Thus, if the force B produces a motion of 10 miles per hour in a direction AB, the body A would move 10 miles along AB in one hour, if acted upon by B alone; and similarly, if the force C produced a motion of 5 M.P.H. in the direction of AC, A would move 5 miles along AC in one hour. If, however, both forces are acting together, A cannot move in the direction AB or AC, but will take up the direction AD, with a velocity compounded from the other two.



(FIGURE 28.) Parallelogram of Velocities.

In Figure 28 let ¼″ represent 1 MPH, then AB equals 2½″ representing 10 MPH; AC is 1¼″ representing 5 MPH and AD 2.75″ represents the velocity A on a scale ¼″ per mile per hour, i.e., 11 MPH, and the direction AD represents the direction which will be taken up by A.

In practice, it is found convenient to dispense with the sides AB, BD and use the "Triangle of Velocities" ACD, to solve the problem.

Triangle of Velocities provides a graphical solution of the various problems arising from the effect of wind on an airplane in flight.

On any triangle, given the magnitude and direction of two sides, the magnitude and direction of the third side is represented by the line completing the triangle.

For instance, it is required to determine the ground speed and track of an airplane, given the wind speed and direction, together with the air speed and course.

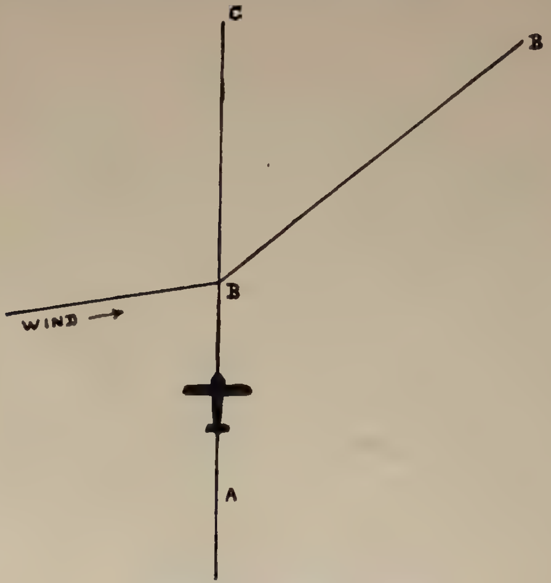
If the two known components are laid off as two straight lines from the same point, any length proportional to the wind speed and air speed, and any directions relative to the components they represent, then a third line completing the triangle will represent the third component, i. e., ground speed and track.

THE TRIANGLE OF VELOCITIES AND ITS APPLICATION.

The velocity is the rate of change of position in a given direction so that it involves both speed and direction. Any velocity may conveniently be represented by a straight line. By employing a suitable scale, the speed may be represented by the length of the line, and by using a suitable reference line the direction may be shown relative to that line. In the graphical solution of problems it is generally most convenient to consider North to be at the top of the paper.

> The Meridian should usually be drawn and the scale employed should be clearly stated.

Track of an Airplane. Effect of wind on an airplane in flight. To find the direction from one place to another use is made of the map, and to maintain that direction the compass is employed. The direction from one place to another can be represented on the map by a straight line or a series of straight lines joining the point of departure and the point of arrival. This direction is called **the desired track.** The distance between the places can be measured by means of the scale. Time taken to fly from point to point can be estimated when **the ground speed is known**; the time at which places on the route will be passed over can be determined by means of the time scale. If the airplane were to fly in still air this would be a very easy problem. However, this is never so in actual practice.



(FIGURE 29.) Effect of wind.

In Figure 29, let the fore and aft axis AB of the airplane be produced to C. By use of the rudder and the indications of the compass, the airplane can be made to move so that the fore and aft axis AB remain parallel to the line AC. If there is no wind or the wind is dead ahead or dead astern **the track will be AC.** The side wind, however, has the effect of pushing the aircraft bodily in the direction in which the air is moving; therefore, the airplane track will not be in the direction AC, but in some other direction BB. The resultant of the forces due to the speed and direction of the airplane and the velocity of the wind will be **called track.**

Track. The airplane on leaving the ground is affected by the moving atmosphere in the same manner as a boat is carried by the tide or by the current of a river.

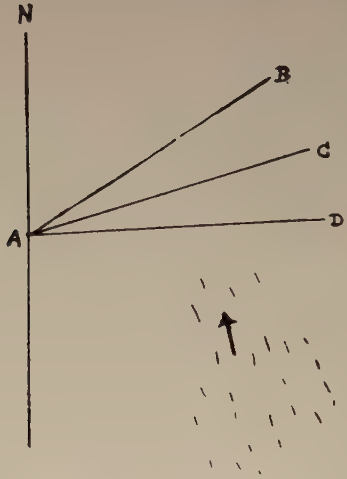
When an airplane is flying up or down wind, the effect will be merely to reduce or increase its speed, the track being coincident with the course steered; but when an airplane is flying in a wind which is blowing at an angle to its course, the element of drift is introduced. From this it is seen that if BB is the desired track and if the airplane is exposed to the wind W, it is necessary in order to follow the desired track that it must steer in the direction AC.

In order to fly an airplane from a point A to a point B distant, for example, 150 miles, it is necessary to note the following:

a. The direction from A to B.
b. The distance of A from B.
c. The direction of the wind.
d. The speed of the wind.
e. The course to steer to make good A from B.
f. The air speed of the airplane.

These six factors constitute three complete velocities, and some of the factors being known, others may be found from a **triangle of velocities.** The direction and distance of the destination from the departure point may be taken from a map and the velocity of the wind may be either known from meteorological information, or found in the air, while the air speed is known from the air speed inductor and computator. The course is maintained by a compass.

Example of Drift. The desired course is A.C. Wind blowing from S.E. causes the airplane to fly along the Track A.B. Therefore, in order to make good the course AC, the machine will have to steer a course AD approximately. (Figure 30.)



(FIGURE 30.) Course to Steer.

Definitions:

Drift is the angle between the airplane's fore and aft line and the track. It is measured in degrees to right or left of the Fore and Aft Line.

Track. The track is the Line on the map or chart along which the airplane is traveling.

Track Angle is the angle which the Track makes with the True Meridian measured clockwise from 0° to 360° from the Meridian.

Air Speed is the speed of an aircraft through the air. It is independent of the motion of the air, i.e., a "Helping Wind" or a "Retarding Wind" does not affect the reading on the Air Speed Indicator.

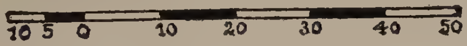
Ground Speed is the actual speed of the Airplane over the ground. It varies with the velocity of the wind.

Drift Calculations. If the following rules are remembered, no difficulty should be experienced in working out Drift Calculations:

WIND. 1. The Wind is always given as "True."
2. Direction is given from the direction it blows, i.e., N. E. wind blows from the N. E.
3. To find course to steer, draw wind—**Down Wind.**
4. To find Track and Ground Speed, draw wind—**Up Wind.**

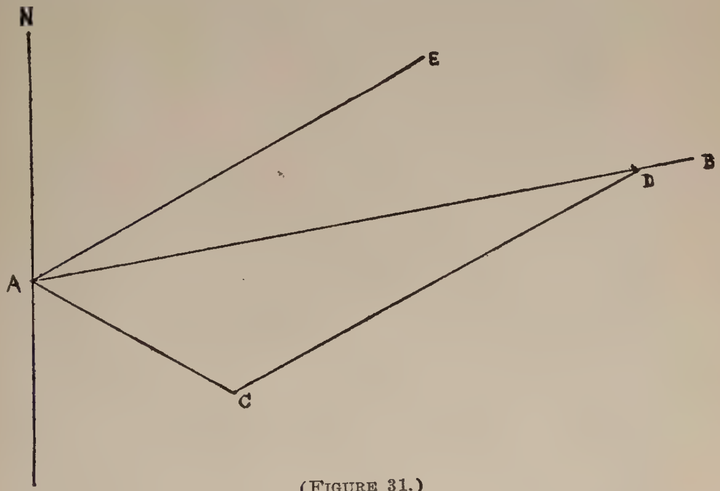
Speed. Ground Speed and Track are calculated together.
Air Speed and Course are calculated together.

N. B. All problems should be worked out from True North, a line of sufficient length being drawn to represent the True Meridian.



Scale of Measure for Figures 31, 34, 35.

(1) **What is the Course to Steer** to make good the desired Track? (Figure 31.) Magnetic Course 80°, Wind 30 M.P.H. from 300° Air Speed 60 M.P.H.



(Figure 31.)

Draw a line representing True North N.A. This is the True Meridian.

From A draw a line at an angle with the True North 80° to B.

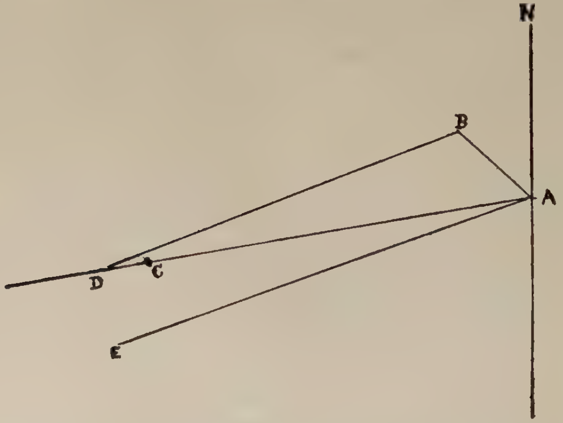
A is the point of Departure and B is the required destination.

From A draw a line down wind, i.e., in the opposite direction from which the wind is blowing, in length equal to the strength of the wind, A.C. With a pair of dividers measure 60 M.P.H. —Air Speed—on the scale. From center C describe an arc cutting the line A.B. at D. The line AE is drawn parallel to CD. The Angle N A E is the Course to steer, 60°. Although the machine will be headed in the direction AE, it will actually be flying over the Course AB and thus counteract the Drift. This is spoken of as "Crabbing into the Wind."

The Ground Speed, it will be noticed is 80 M.P.H., so that, although a side wind, it is a "Helping Wind."

N. B. Wind is always given as "True." Direction is given from the direction it blows, i.e., N. E. Wind blows from the N. E.

(2) **To find the course to steer** to make good a track of 260° —True—Wind 20 MPH S.E., air speed 80 MPH. (Figure 32.)



(Figure 32.)

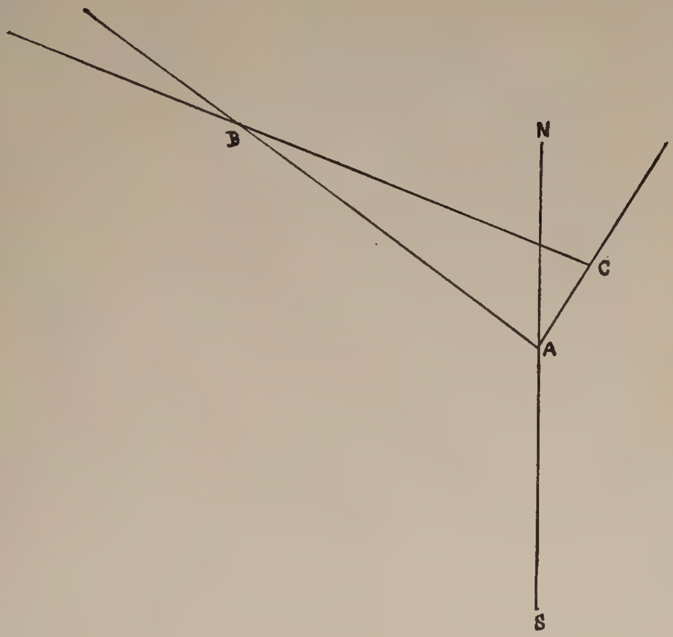
The direction from which the wind blows is always given. (Scale: 40 miles to 1 inch.)

From A, draw AB 20 miles to scale 315° to represent the wind—down wind—. From A, draw AC to represent the track. With a pair of compasses measure 80 miles on the scale—Air Speed, and from B, cut in AC to point D. Join BD.

The triangle of velocities is now complete. By placing a protractor at B and reading the direction of the line BD, the course is seen to be 250°.

The line AE is the heading of the airplane.

The distance from A to D represents the ground speed—100 MPH.

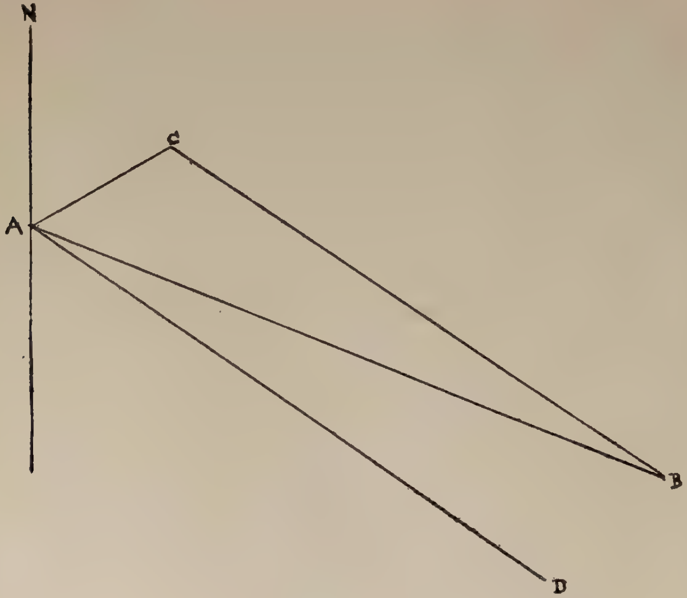


(FIGURE 33.)

3. **To find the track and ground speed** when the course, air speed and wind velocities are known. Scale: 40 miles to one inch.

Course 306°—magnetic—, air speed 80 MPH, wind from 30° —20 MPH. Find the track and ground speed. (Figure 33.)

From A, draw AB 80 miles 306°—magnetic—. From A, draw AC 20 miles, 30° noticing that it is necessary to draw the wind line in the direction from which the wind blows in order that the direction of the components may follow each other. Join CB. Thus CB gives the track 291°—magnetic—and the ground speed 80 MPH. (If the airplane flew from the point A along the course AB, its actual track would be on a line from A parallel to CB.)



(FIGURE 34.)

(4) Find Track and Ground Speed.

Course 112° True; Wind 20 M.P.H. from 60° True; Air Speed 90 M.P.H. (Figure 34.)

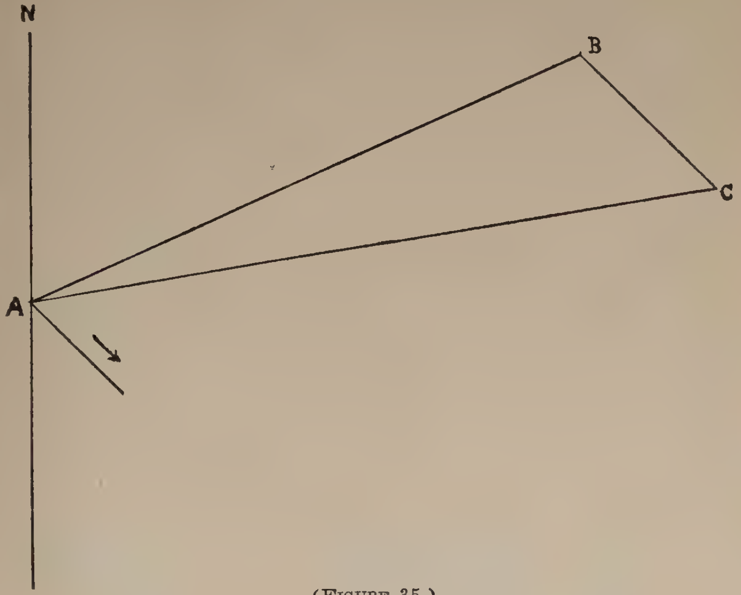
Draw A. B. 90 miles to scale, 112°; from A draw A. C. 20

miles 60°—**Up Wind**—Join CB; CB. gives the Track, 125° True; Ground Speed 80 M. P. H.

If the airplane flew from the point A along the Course A.B., its actual Track would be on a line parallel to C.B., e. g., A. D.

(5) Find strength and direction of the wind: Course, Air Speed, Track and Ground Speed being known.

Magnetic Course 65°; Air Speed 80 M.P.H.; Track 80°; Ground Speed 92 M.P.H. (Figure 35.)



(Figure 35.)

From A, draw A.B. 80 miles to scale 65°. This represents the course steered and Air Speed.

From A, draw another line A.C. 80°, 92 miles to scale—representing Track and Ground Speed. Join B.C.

B.C. gives the direction from which the wind is blowing—315° Magnetic.

By referring to the scale the distance B.C., the strength of the wind is found to be 25 MPH.

Drift. Table for finding the speed of the wind by flying up wind and turning through 90°.

The speed of the wind is taken out from the column headed by the air speed of the plane opposite the angle of drift observed. Thus, if the air speed were 80 MPH and the drift 10°, the speed of the wind is 14 MPH.

The wind speed is correct to the nearest mile an hour.

Angle of Drift	AIR SPEED—MILES PER HOUR						
	60	70	80	90	100	110	120
5°	5	6	7	8	9	10	11
10°	11	12	14	16	18	20	21
15°	16	19	21	24	27	30	32
20°	22	26	29	33	37	41	44
25°	28	33	38	42	47	52	57
30°	35	41	47	53	58	64	70

(TABLE 2.)

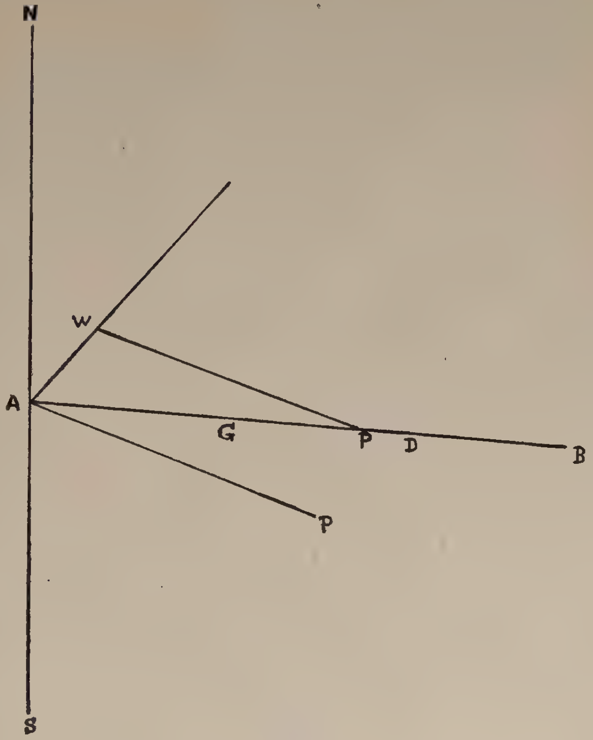
Calculation of Dead Reckoning Time. Dead Reckoning covers all calculations where Course and Distance in Latitude and Longitude depend upon data given by the Air Speed Indicator and the Compass.

d = Distance = Time × velocity
t = Time = Distance div. by velocity
v = Speed = distance div. by time

$$\text{Then } d = t \times v, \qquad T = \frac{d}{v}, \qquad v = \frac{d}{t}$$

For Example: An airplane, air speed 60 MPH, is to proceed from A to B, Distance AB is 110 miles and desired track 95° True. Wind is 20 MPH 220° True. Required to find True Course, Ground Speed, Dead Reckoning time and Drift. (Figure 36.)

Scale 40 miles to one inch.



(FIGURE 36.)

Join AB, the desired track. From A, lay off AW in the direction towards which the wind is blowing, that is angle NAW = 40°. Make AW ½ inch long to represent 20 miles. With center W and radius 1½″, representing an air speed of

60 MPH, describe an arc cutting the track in P. Then the angle WP makes with the Meridian is the True Course.

If AP is laid off from A parallel to WP, then the angle NAP = course i.e. 107° True.

Angle PAP = Drift 12° to port.
AP = Ground Speed to scale, i.e., 72 M.P.H.

Calculation of Dead Reckoning Time. Since the ground speed is 72 MPH and the distance AB 110 miles:

$$\frac{d}{t} = v = \frac{110}{72} = 1.53 \text{ hours}$$
$$= 1 \text{ hr. } 32 \text{ minutes}$$

The Dead Reckoning Time for any place on the track AB can also be found. For example: C is 40 miles from A and will be reached in 33 minutes, D is 80 miles from A and will be reached in 66 minutes. (Figure 36.)

Radius of Action. The Radius of Action of an airplane is the furthest distance which it can travel, on any course, and still allow sufficient gasoline and oil to enable it to return to a prearranged landing ground. Normally, the radius of action of an airplane is calculated as the maximum distance which it can proceed in any direction and allow it to return to its starting point; but the radius of action, in some instances, may be increased by returning to a base, other than the point of departure. In calculating the radius of action of airplanes it is advisable to allow for a margin of safety, i.e., **20%** of the **fuel** carried to be deducted. The following example demonstrates the method whereby the radius of action can be calculated.

It is simpler, before working out the problem, to deduct the amount to be kept in reserve.

The formula is as follows:

When

R represents the radius of action in miles.
P represents the Petrol hours.
O represents the Ground speed on the outward track.
H represents the Ground speed on the homeward track.

Then

$$R = P \times \frac{O \times H}{O + H}$$

The proof of the formula is as follows:

$$\frac{R}{O} = \text{time taken on the outward journey.}$$

and

$$\frac{R}{H} = \text{time taken on the homeward journey.}$$

then

$$P = \frac{R}{O} + \frac{R}{H} = \frac{R(O+H)}{O \times H}$$

whence

$$R(O+H) = P(O \times H)$$

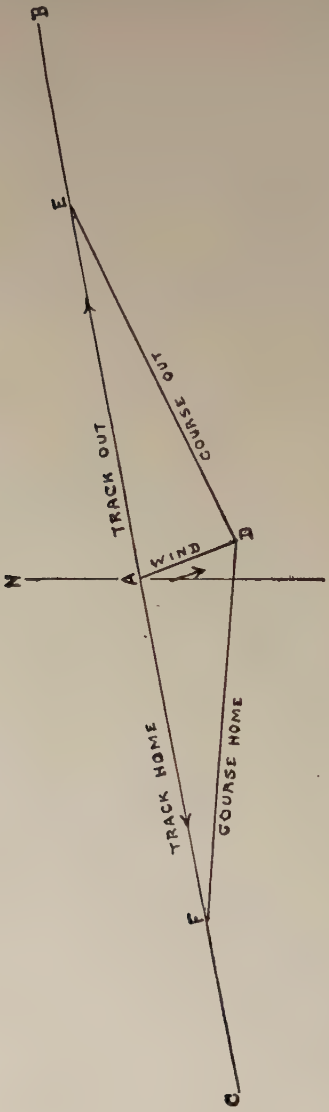
$$\therefore R = P \times \frac{(O \times H)}{(O+H)}$$

Example: To find the radius of action of an airplane along a track 80° True. Air Speed 80 miles. Wind from 340° True, 20 miles per hour. Fuel for six hours is available. (Figure 37.) Scale 40 miles to 1 inch.

Let A represent the point of departure.

From A draw AB, 80° True.

AB represents the outward track.



(FIGURE 37.)

Produce BA to some point C. Then AC represents the homeward track.

From A, draw AD, 160° True, 20 miles; this represents the wind—down wind.

With center D and radius 80 miles to scale (Air Speed) describe arcs cutting AB in the point E and AC in the point F.

Join DE and DF.

Then DE represents the course out and DF the course home.

AE represents the ground speed out and AF the ground speed home.

Radius of action returning to same base **by formula.**

From the figure the course out is 65° True, and the Course home 275° True. The ground speed out is 82 miles and the ground speed home 73 miles.

To find the radius of action from the formula:

$$R\ 6 \times \frac{(82 \times 73)}{(82+73)}\quad \frac{6 \times 82 \times 73}{155}\quad 232 \text{ miles approx.}$$

The time to turn can be found by dividing the radius of action by the outward ground speed.

$$\frac{232}{82} \text{ hours} = 2 \text{ hours } 50 \text{ minutes approximately.}$$

The problem can also be solved by plotting. Using the same figure, proceed as follows:

Draw AG up wind 20 miles.

From A, draw AH parallel to DE, the course out.

From G to AH, draw GJ parallel to DF, the course home.

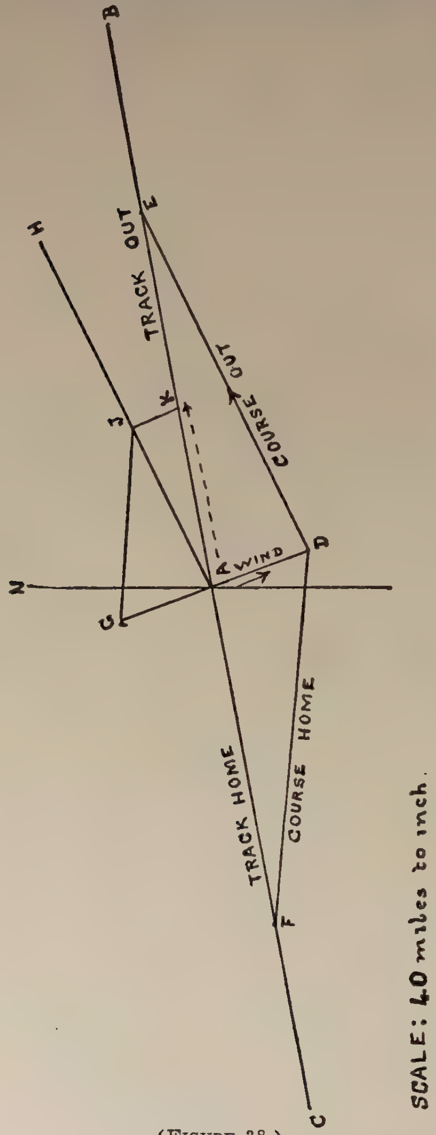
From J to AB, draw JK parallel to GD (the wind line).

Then AK gives the radius of action for one hour.

From the figure AK represents 38½ miles.

Then the radius of action for six hours equals

(38½ miles × 6) = 231 miles.


B
E
TRACK OUT
H
COURSE OUT
K
J
D
A
WIND
N
G
TRACK HOME
COURSE HOME
F
C
SCALE: 40 miles to inch.

(FIGURE 38.)

Table Giving Approximate Radius of Action for One Hour

Air Speed	STRENGTH OF WIND							
	5	10	15	20	25	30	35	40
60	30	29	28	27	26	24	22	..
65	32	32	31	30	29	27	25	..
70	35	34	34	33	32	30	28	26
75	37	37	36	35	34	33	31	29
80	40	39	39	38	37	36	34	32
85	42	42	41	41	40	38	37	35
90	45	44	44	43	42	41	40	38
95	47	47	47	46	45	44	43	41
100	50	50	49	48	48	47	45	44
105	52	52	52	51	50	49	48	47
110	55	55	54	54	53	52	51	49
115	57	57	57	56	55	55	54	52
120	60	60	59	59	58	57	56	55

(TABLE 3.)

CHAPTER VI.

DIRECTIONAL WIRELESS

Navigation by Directional Wireless has already proved successful, and will eventually develop into the recognized method of navigation for long distance flying, for it is comparatively simple and accurate.

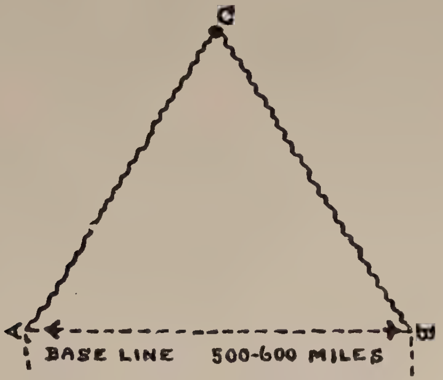
With the aid of directional wireless the navigator is no longer dependent upon ground objects for fixing position and the difficulties presented by fog, cloud or by sea journeys do not arise. The navigator of aircraft equipped with wireless telephone and wireless direction finder, need have but few fears of losing position, while the consequent accurate time-keeping on long journeys will assist in making commercial aviation successful.

The action of the **wireless direction finder** depends upon the fact that the maximum induced current in a frame aerial occurs when the plane of the aerial is **parallel** to the direction of the transmitted wave, and decreases to a minimum when at right angles to this direction.

Two triangular or rectangular shaped aerials with planes vertical and at right angles are connected in series to two field coils also at right angles, in the center of which is mounted a **search coil** which may be rotated in a horizontal plane about the vertical axis common to the two field coils. The search coil is connected to receivers and has a pointer mounted above it, working over a **fixed disc graduated** in degrees. Thus any angle between the search coil and one of the frame aerials may be read off, and if the direction of the aerial from North is known, the angle between the Meridian and search coil is also known.

Suppose the **direction** of an in-coming wave coincide with the plane of one of the coils. A current is induced in this aerial only, and flows through the expanding field coil, producing a magnetic field, which in turn causes a current to flow through the search coil. This current will be a maximum, i. e., produce the loud note in the receivers, when the search coil is at right-angles to the field coil. The pointer now indicates the direction of the incoming wave, and consequently the direction of the transmitting station.

If the **direction** of the incoming wave is **not coincident** with either of the aerials a current is induced in both, and produces two magnetic fields at right angles to each other around the field coils. The direction of the resultant of these two fields depends upon the current induced in each aerial by the incoming wave, and the current induced in the search coil is maximum when the resultant field is coincident with the axis of the search coil. In this position the **pointer indicates** the direction of the incoming wave, and therefore, of the **transmitting station.**



(FIGURE 39.) Transmitting Stations.

Suppose now that an airplane at C, Figure 39, is equipped with this apparatus, and that two bases, A and B, are transmitting code signals. If the navigator at C knows the **position** of A and B, and reads off the directions of the incoming waves by the direction finder, he may set off the reciprocals of these angles on the map from A and B, respectively, and the **inter-**

section of the "position lines" gives the fix for C, and its latitude and longitude are read off from the chart.

Alternately the airplane may be equipped with transmitter, and each base may have a direction finder. Then A and B read off the angle of the incoming wave and communicate the information to a central station, where the "**fix**" is determined and the information transmitted to the airplane.

Allowance must, of course, be made for the "**Run**" of the airplane between the time of measuring the angles, and of determining latitude and longitude from the chart. The possibility of error arises in measuring directions of incoming waves, owing to the fact that the wave follows a great circle, which on the Mercator's Chart is a curve. So that if the position line is drawn as a straight line, the fix will be inaccurate, and either an allowance called **conversion angle** must be made to correct this Figure or a Gnomonic Chart should be used for the "**Fix**," for on this projection the Great Circle may be drawn as a straight line. For distances less than 50 miles the error is negligible.

Wireless waves travel in straight lines so that all Radio bearings are Great Circle Bearings. As bearings from a station several hundred miles away may be used, the plotting of lines of a bearing obtained by Radio on a map or chart must be carefully figured.

On all maps, including any on Mercator's Projection, a straight line on the map represents very nearly a great circle on the earth. Therefore, provided both the Radio station and the airplane lie in the area shown on the map, radio **bearings** may be **plotted** directly without appreciable error.

The angle between a Great Circle and Rhumb Line is called the conversion angle. The **Conversion Angle** may be calculated from the formula:

Conversion Angle = ½d. Long. × sin. Mid-lat.

In practice it is sufficient to take the difference of Longitude and the middle latitude (i. e., the latitude mid-way between the two positions) correct to the nearest degree.

The approximate **D.R. position** must be known in order to find the conversion angle, but a considerable error in D.R. position will not seriously affect the calculation.

An example will make its use clear. A table of variations of the conversion angle for middle latitudes 49° to 59° is worked out. In this table the value of ½d. Long. is 1°. A similar table may be worked out for any part of the world without difficulty. (Table 4.)

Allowance must, of course, be made for the run of the airplane between the time of measuring the angles, and of determining latitude and longitude from the chart. The possibility of **error** arises in measuring directions of incoming waves, owing to the fact that the wave follows a great circle.

Middle Latitude	Conversion Angle
49°	45′
50°	46′
51°	47′
52°	47′
53°	48′
54°	49′
55°	49′
56°	50′
57°	50′
58°	51′
59°	51′

(TABLE 4.) Values of Conversion Angle.

Example: Calculate the conversion angle with the D.R. position of the airplane as 50°, 21′ N., 06°, 20′ W., and the position of the Radio station as 54°, 14′, N. 15°, 19′, W.

d. Long. (approximately) = 9°.
½d. Longitude = 4°.5.
Mid. Latitude = 52°

From the table the conversion angle for Mid.-Lat. 52° and ½d. Long. 1° = 47′. Multiply 47′ by 4.5., then the conversion angle is 211′ or 3½°. When the conversion angle has been found, it must be accurately applied to the radio bearing before the position line can be laid down.

To find the Mercatorial Bearing the following rule applies. In the Northern Hemisphere, add the conversion angle to Great Circle bearings between 0° and 180° and subtract the conversion angle from Great Circle bearings between 180° and 360°. In the Southern Hemisphere the converse applies.

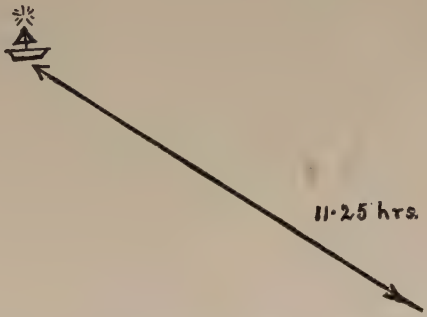
A Mercatorial Bearing so obtained may be drawn on the chart and the portion of it in the neighborhood of the D. R. position will form a reliable position line. It is quite possible to obtain position lines from a station as far distant as 1,200 miles without appreciable error.

CHAPTER VII.

FIXING POSITION.

When owing to weather conditions or other causes, it is impossible to locate the exact position by map reading, other methods can be used.

If a line be drawn on a map and it is known that the position of the airplane must be somewhere upon it, the line is called the **position line.** Thus, if by some means it is observed that a light-ship bears 300° (Magnetic) at a certain time from an airplane, the position line may be drawn from the light-ship on the chart in the direction 120° (Magnetic). (Figure 40.)

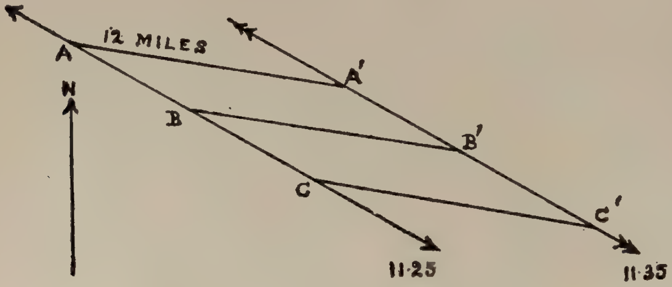


(FIGURE 40.) Position Line.

It is always most important that the exact time of the observation be written against the position line. All the positions lines obtained by direct observation must be distinguished by drawing single **arrow heads** near each end. (Figure 40.)

It frequently happens that only one position line can be obtained at a given moment, and although no fix can be obtained from this solitary observation, it may be used later when another observation of the same or a second object can be obtained.

Suppose the arrow-head in Figure 41 bears 300° (Magnetic) at 11.25 hours and at 11.35 hours, it is possible to take an observation on another object. Provided the track and ground speed be known, it is possible to transfer the first position line. Let the track be 100° (Magnetic) and the ground speed 72 MPH; at 11.25 hours, the position of the airplane must have been somewhere on the position line such as A, B or C. In 10 minutes the airplane will have travelled 12 miles 100° (Magnetic). Then, if a line (for example AA′) be drawn 12 miles to scale, 100° (Magnetic), and through the point A′ a line be drawn parallel to the first position line, it is clear that at 11.35 hours the airplane must be somewhere on the second line, which is called a **transfer position line.**



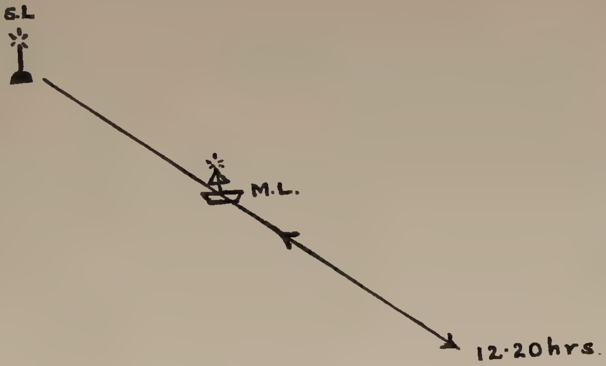
(FIGURE 41.) Transfer Position Lines.

Transfer position lines must always be distinguished by **double arrow heads.**

The distance made good between the direct and transfer position lines is called the **run.**

Since the track and ground speed are rarely known with absolute accuracy, position lines should not be transferred when it can be avoided, and no great reliance can be placed upon a position line which has been transferred for a double run.

When two objects on the earth's surface appear to an observer to be in line with him, they are said to be **in transit** and two objects in transit give a position line. Objects should not be selected too near the airplane. Three miles may be taken as a suitable distance for the nearest object. The Greek letter Ø is used to denote transit in the air navigator's log.



(FIGURE 42.) Transit.

Suppose the Statue of Liberty and the Marr Lightship be observed in transit at 12.20 hours a position line should be drawn on the chart as shown in Figure 42. The **entry** in the **log book** should be made as follows, the nearer object being named first.

12.20 Marr Lightship Ø Statue of Liberty.

Fixes. When two or more position lines intersect, the **point of intersection** constitutes a **fix.** When one or more of the position lines have been transferred, the resulting fix is known as a **running fix.** In order to obtain a reliable fix from position lines certain considerations must be taken into account. The objects on which bearings are taken must be selected so that the position lines cut at an angle of about 90° whenever possible. No reliance can be placed on the fix where the position lines meet at an angle of less than 30°.

When any choice exists, **bearings** should be taken on **objects near** the airplane in preference to those a great distance away, because any error in bearing in a near object, has less effect on the accuracy of a fix than the same error in the bearing of a more distant object when the position lines are plotted.

Position lines should not be transferred when it is possible to avoid it.

Bearings which are to be used for fixing position should be taken as nearly simultaneously as possible.

Before fixing position, the observer should be quite clear as to all the objects he proposes to use and should make sure that they are marked on the map or chart. The names of the objects should be written in the log and the observations then taken as quickly as possible, consistently with accuracy. The object, the bearing of which is changing most rapidly, should be observed last, the most favorable conditions being when the first of the two objects is observed nearly a head and the second nearly a beam.

When possible, a **third position line** should be used as a check. When three position lines are used, it will be the exception rather than the rule for them all to pass exactly through one point.

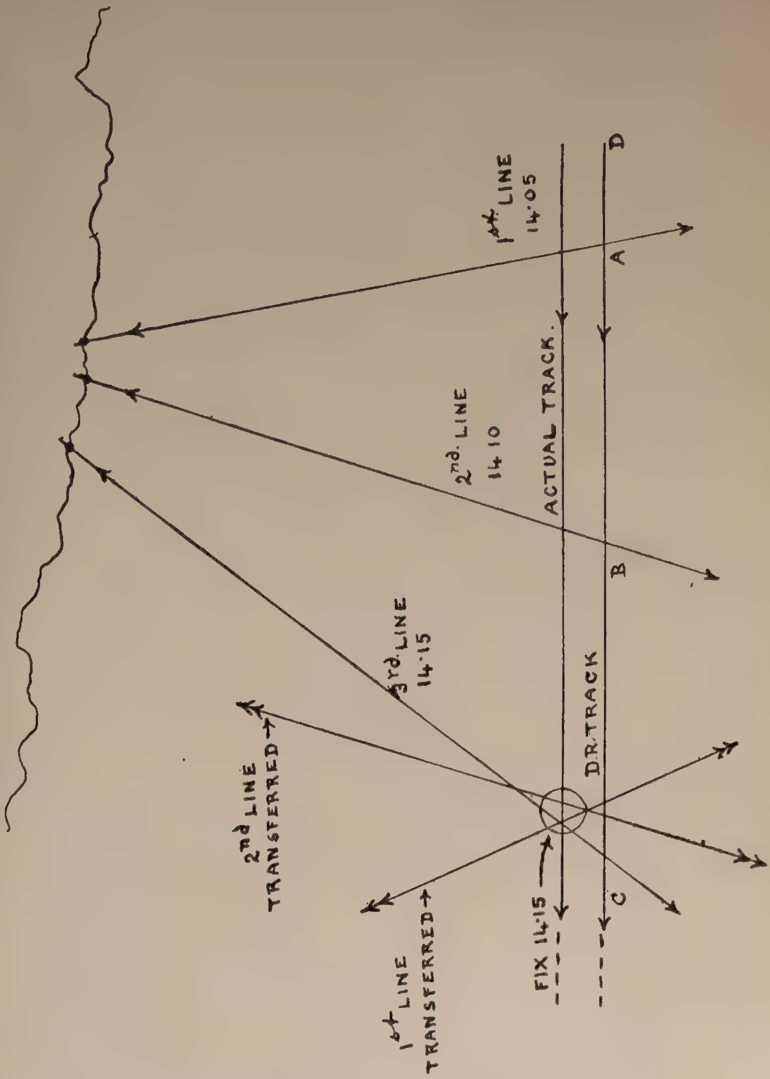
They will generally form a small triangle, which is known as "**a cocked hat.**" If the cocked hat is small, the position of the airplane may be taken as inside it, but if it be large, the work on the chart should be carefully revised and if a better result is not obtained after revision, it should be disregarded.

When bearings are taken by compass, the **deviation** to be used to correct the bearings is that of the course of the airplane at the moment of observation. Thus, it is essential to know the course when bearings are observed.

A fix is of little value unless the exact **time** it was obtained is recorded.

The fix must always be distinguished from any other intersection of two lines by drawing a **small circle** around it.

Although **lines of bearing** obtained visually are arcs of great



(FIGURE 43.) Running Fix.

circles, the position lines are so short that they may be plotted either as Rhumb Lines or great circles, according to the projection of the map or chart being used, without appreciable error.

It is best to show position lines with a single headed arrow, and transfer position lines with a double headed arrow.

Let D be the departure point, and A, B and C, three fix points, on which bearings are taken at 14.05, 14.10, 14.15, respectively. Lay off the position lines from A, B, C. Transfer A's bearing, allowing 10 minutes for run up to 14.15, the time of C's bearing. Transfer B's bearing, allowing for five minutes run. These two transfer position lines, together with C's bearing, form a **small triangle** the center of which may be considered for all practical purposes to be the fix 14.15. (Figure 43.)

N. B.

(a) Bearings must be **observed** practically simultaneously or there will be considerable error.

(b) The **Bearing** of an object that is changing very rapidly should be **taken last.**

(c) Great **accuracy** must be observed in taking a fix, and this depends to a great extent on the distance and angle at which the two lines cut. The less the distance and the nearer the angle is to 90°, the more accurate will be the fix.

CHAPTER VIII.

CROSS COUNTRY FLYING.

The altimeter is a special form of Aneroid Barometer which expresses changes in pressure in terms of height. The pressure of the air, however, depends not only on height above sea level, but also upon various other meteorological conditions which cannot be allowed for in the instrument, so that an altimeter rarely, if ever, records the actual height of the airplane above the ground. It is important to realize further that an altimeter which has been set to zero at a certain aerodrome before the commencement of a flight, only gives approximate records of altitude relatively to the level of the aerodrome.

When the instrument was designed it was necessary to assume an ideal atmosphere, a constant temperature of 10°C. 50°F, and a barometric pressure of 29.9″ of mercury being taken. In practice this constant temperature never exists, so that the height recorded by the altimeter may be distinguished from the actual altitude by calling it the **isothermal height.**

Generally, the barometric pressure at ground level will not be 29.9″. Thus if an altimeter at ground level reads zero, when the barometric pressure is 29.9″, it would indicate a height of 1,020 feet while still on the ground when the barometer reads 28.8″. The difference between the actual and assumed pressures must be allowed for by **turning the dial until the instrument reads zero** on the ground before beginning a flight.

Before undertaking a long flight, full advantage must be taken of all available **meteorological information.** It is not sufficient to obtain only an estimate of the wind and atmospheric conditions at the departure point; careful study of the weather charts, issued by the Weather Bureau, will give valuable indications of the types of weather and changes in wind to be expected throughout the course of the flight.

Wind directions are given relative to the True Meridian in

Form P-L-8

PILOT'S LOG

NAME L. Ponton de Arce.

ADDRESS Old Colony Airways.

LICENSE No. A1.

CLASSIFICATION Transport

Date	No. of Flights	Time in Air	Distance Flown	Reg. Mark or Type of Plane Used	Nature of Flights	Certified by
Brought Forward	4005	3025.	295.000			
7/10/28	2	1·50m	135	Ryan.	Cross-Country —	M. Eyke
					Revere Airport to	
					Portland and return.	
7/12/28	6	2·10	200	Eaglerock	Flying instruction	M. Eyke
7/14/28	4	1·30	140	Eaglerock	Sales demonstration.	M. Eyke
7/15/28	1	3 15	360	Ryan.	Passengers. Two.	E. Radische
					New York and return.	
7/16/28	1	·45.	60	Eaglerock	Testing new plane.	M. Eyke
					Flying right wing low.	
7/18/28	1	2·25.	240	Ryan	Photography.	M. Eyke
					24 Exposures.	
					Visibility good.	
					Survey work. Beverly.	
7/19/28	1	·35	40	Eaglerock	Night Flight. Test.	M. Eyke
Carried Forward	4021	3037·30	296,175			

Meteorological Charts and the speed of the wind is given in "Miles per hour."

Maps should be carefully prepared before a flight. The track should be laid down and the country to be flown over studied. Distances should be measured accurately and noted. Particular care should be taken to pick out conspicuous landmarks on the course and to tabulate the D.R. Time which it will take to reach each of them.

As it is generally easier to consider the relation of speed to time rather than to distances on a map, some form of **time scale** should be used whenever possible. Particular attention must be given to the heights of different parts of the track above sea level.

On taking off the pilot **flies up-wind** to ensure that the wind direction given in the Meteorological Report is approximately correct.

Under normal weather conditions the map and ground should be compared frequently; when flying above the clouds, as frequently happens in a long distance flight, the pilot should note on the map the area which he should be passing so that when he comes down through them he is prepared for the landmarks he may expect to see.

Ground Speed. The Ground Speed of the plane should also be frequently checked during a long flight. The distance between two points being known, and the time observed to fly from one to the other, a simple formula will give the required information.

For example: The distance from East Boston to Old Colony, Revere, is 15 miles. A plane flies between the two points in 10 minutes.

To find the Ground Speed per hour:

$$15 \times \frac{60}{10} = \frac{15 \times 60}{10} = 90.$$

Ground Speed 90 M.P.H.

The distance from Dixon Field to Hartford is 20 miles. Time from one point to the other is 12 minutes.

$$20 \times \frac{60}{12} = \frac{20 \times 60}{12} = 100.$$

Ground Speed 100 M.P.H.

Therefore, the distance between two known points multiplied by 60 (one hour in minutes), and divided by time taken to fly between these points is the ground speed per hour.

Time. Knowing the Ground Speed, to find Time it will take to cover a certain distance, divide mileage to be covered on ground (Track) by Ground Speed.

Distance from New York to Albany 140 miles.

Ground Speed 80 M.P.H.

$$\frac{140}{80} = \text{1 hr. 45 minutes.}$$

This will also determine the amount of fuel necessary for the flight. A safety margin of 20% fuel in addition should be carried.

There can be no doubt about reaching the desired destination so long as it is possible to check and, when necessary, modify the course **steered by observation of drift.** Thus, the angle of drift is a most important factor and an opportunity to check it must never be neglected. Suppose that after a period of time visibility deteriorates and mist and rain sets in. The pilot will find himself flying over a country which he can only see directly below and of which the ground features are exceedingly difficult to distinguish. He can no longer rely upon recognizing his course by comparing the ground with the map. He must, therefore, concentrate entirely upon flying a **correct compass course** in accordance with his preliminary calculations.

No experienced pilot **will lose himself** even in the worst weather—always excepting thick fog or an extensive blizzard

—provided that he has taken proper precautions before and at the commencement of the flight.

When doubt as to his **actual position** arises, the pilot should have a general idea from his map and record of D.R. times as to the district he is over. He should then try to locate on the ground, some distinctive landmark shown on the map. Failing this, and still continuing his course, he should select some conspicuous landmark, or combination of landmarks, on the ground, and then keeping it in view, try to identify it on the map.

If, for example, a railway be selected, its direction should be carefully noted and then an attempt made to identify features such as bridges, stations, divisional points, etc. If this is unsuccessful, the pilot should determine from the map whether there is another railway having approximately the same bearing, within a reasonable distance of the first. By a process of elimination, the position should eventually be identified with certainty, and although this appears a lengthy operation it is, in fact, generally simple and effective, provided the pilot can read his map quickly and intelligently.

When the pilot is, for the time being, definitely lost, he may be able to locate himself by a careful revision of his D.R. data. He should choose a **conspicuous landmark** on the ground and keep it in sight while he attempts to find the reason for his deviation from the desired track. It will probably now be found that his rough log proves very valuable.

The pilot should satisfy himself on the following points:

1. Is there any reason to conclude that the wind has changed.
2. If so, how would this change affect the track and ground speed.
3. For how long and in what direction has the course been altered to avoid clouds, storms, etc.
4. Has the average air speed been altered from that upon which the original calculations were based by change of altitude, throttle adjustment, etc.

5. What changes of wind might be expected with changes of altitude.
6. Has the drift recently observed differed greatly from that obtained at the beginning of the flight.

If none of these queries helps to identify the position, the pilot must fly, provided he has sufficient fuel, until he observes some unmistakable landmark from which he can set a course for his desired destination.

The last two expedients are to fly low and read the name of a railroad station **or to land** and ask the position; but, except under very adverse weather conditions, neither should ever be necessary.

Example of Time Scale.

Wind 263° Mag. 28 M.P.H.

	Track M.	Distance m.	Course M.	E.T.A. Hrs.	Actual Time Hrs.
Boston	—	—	—	—	10.00
Dedham ...		23	286°	10.21	10.21
York	297°	38		10.57	11.03
Albany		42		11.36	11.35
Bedford ...		18		11.54	11.56
Ayrton	289°	22	280°	12.13	12.19
Richmond ..		32		12.44	12.40
Easton	287°	56	279°	13.46	13.30
Rome		16		13.55	13.44

(Table 5.)

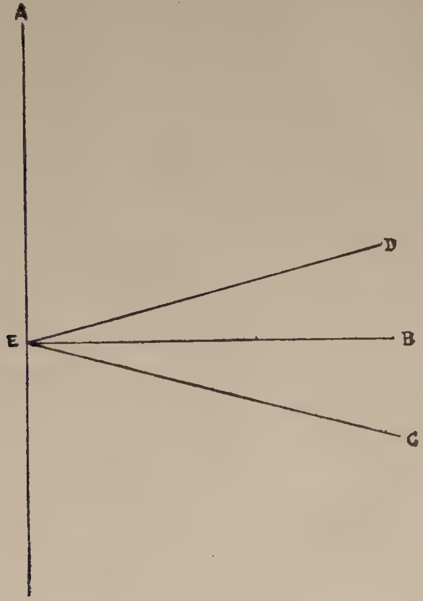
At 10.00 hours the pilot takes off, setting course 287° Compass. Table 5 is made out, complete except for the "Actual Times," which is entered while in the air.

It should be noticed that the **effects of the wind backing** has been to place the track made good to Northward of the desired track and to advance the D.R. time.

M.—Magnetic. m.—Miles. E.T.A.—Expected time of arrival.

"Rotating Compass" Error. In clouds, fog, or when night-flying, the compass card will often appear to be rotating, when in reality the aircraft is turning about the card. This should be at once corrected, not by attempting to "chase" the compass card by turning the airplane sharply, but by centralizing the controls and steadying the compass to the new course; by turning slowly and steadily back to the original bearing the required course can then be regained.

If the airplane has swung off its course to the extent of some 10° or 20°; the pilot must remember that if he merely returns to his original course, he will not be traveling in prolongation to the original track, but parallel to and one side of it. Should the airplane constantly swing away in the same direction, this error may ultimately become considerable. This error may be



(FIGURE 44.)

corrected if, when the airplane swings to port or starboard of the course, the pilot over-corrects to the extent that he considers necessary instead of resuming his original course at once. In this way the desired track can be regained.

For example, suppose a pilot steering East 90°. While flying through the clouds the airplane swings off 15° South, i.e. to a course 105°. As soon as the pilot notices this, he should **over-correct by the same amount**—that is 15° ; in other words he changes course from 105° to 75° and, after remaining on this course until he thinks he has counteracted the error, he can then change back to his original course of 90°.

AEB is the desired course—AEC the course being flown—AED the course to fly until error has been counteracted.

Night flying requires special training and experience, and although the general principles of Navigation are the same greater difficulty is experienced in locating landmarks.

Along the mail routes lighthouses and beacons have been erected and are of great assistance to the pilot.

Although a pilot can fly by instruments alone, when covering long distances it is a great physical and mental strain, and therefore he depends to a great extent upon **landmarks.** Towns, railway stations, railroad roundhouses, have a characteristic arrangement of lights and may thus be recognized by night, as they are known by day, from their shape and general appearance. Industrial cities and towns offer excellent landmarks in the shape of factories, high buildings with special lighting effects, blast furnaces.

When the pilot has left the ground and adjusted his course, he should endeavor to **obtain a line on some distant light or bright star,** which if kept in line with a point on the airplane will greatly assist him in maintaining his course. The course should be frequently checked to provide against drift if the night is at all windy.

Visibility at night varies according to atmospheric conditions and to the light thrown by the moon. It changes much more than by day on account of the varying amount of light given by the moon. On full and half moon nights when the moon is low the effect of shadows cast by the tree and other ground features is very great and apt to be confusing.

Lighthouses and large fires can be seen from a great distance but are not so visible in bright moonlight as on a dark clear night. On clear moonlight nights when the ground is covered with snow **visibility** is excellent. Woods and forests stand out clearly. Rivers and lakes are easy to distinguish even on dark nights.

Railways can be seen on moonlight nights by the reflection of the moon but are not easy to follow on dark nights. Trains especially if steam or smoke is being emitted from the engine can be seen from a long distance owing to the reflection of the fire on the steam. Cement roads also show up clearly even on dark nights. Practically all main roads are of cement and are easy to distinguish through the headlights of the automobiles traversing them.

Inclement weather is a source of far greater trouble to the pilot at night than by day. Fogs, blizzards and ice are the three most dangerous conditions with which the night-flying pilot has to contend.

A light, or ground fog, extends to approximately 1,000 feet from the ground and can be flown over, the lights of cities, towns and beacons being observed sufficiently, though dimly, to enable the pilot to check his course. To attempt to fly through thick fog, to the average pilot, is suicidal, particularly in hilly country. The ability to fly "Blind" for any appreciable distance is exceptional and few pilots have it. If it is impossible to get over or round a thick fog, the only recourse is to land on a suitable field or return to the point of departure.

Visibility in a snowstorm is extremely poor, and practically nothing can be seen of the ground ahead. By looking straight down, however, the ground may be observed and no difficulty should be experienced in landing. No attempt should be made to land in a severe blizzard.

The greatest of all hazards the night-flying pilot has to contend with is ice. Due to the experiences of the pilots flying the Transcontinental Mail route much valuable data is available on this subject.

With temperature varying in the neighborhood of freezing point to approximately 10° above zero, fahrenheit, the fabric, struts and wires are quickly covered with ice, due to the moisture in the air. Ice is also collected on the propeller, the uneven coating of which causes intense vibration through the propeller being thrown out of balance. It is possible, sometimes, to fly through the clouds into a warmer strata of air, and thus lose the ice that has accumulated on the airplane. The greater the height the lower the temperature, and it is therefore possible, the nature of the ground permitting, to fly below the freezing zone in a warmer strata of air. This is particularly the case in the Spring and Summer.

The uneven load and the added resistance affect the controllability of the airplane and the pilot will be forced down. In this event, the airplane must be landed **from 20/30 miles an hour faster** than its normal landing speed. With a temperature below plus 10° (degrees) fahrenheit, the clouds are composed of minute ice crystals that cannot and do not freeze on the ship.

As an accessory to his compass, the night-flying pilot should learn to recognize the **principal stars** and should at all times be able to locate the North Star. It is often of assistance to "Set" a star Globe or Chart before flight so that the rough bearings of the **principal stars** or constellations may be known, but it must be borne in mind that stars appear to revolve anti-clockwise round the North Star through an angle of about 15° in one hour. Stars having an altitude greater than 30° are of little value to ascertain direction.

Night-flying airplanes must have the following **special equipment**: three navigation lights—a green light on the starboard side, a red light on the port side, and at the rear and as far aft as possible a white light shining rearward—visible at a distance of from two to three miles. These lights are compulsory. The airplane must also be equipped with electric landing lights, and a Very's pistol, flares or approved equivalent of a Very's pistol.

On the Air Mail 'planes, two large magnesium parachute flares, one of which will light one square mile of area brilliantly from an altitude of 2,000 feet, are carried. They are for use in case of a forced landing and burn for approximately five minutes. They are more generally used than the landing lights because of the many obstacles about the emergency fields.

CHAPTER IX.

MAGNETISM.

A knowledge of Magnetism is essential to the Pilot, in order that he may understand the forces which influence the compass. Magnetism is the property of attracting iron or steel which is peculiar to certain substances.

Terrestial magnetism is a force which exists all over the world, and exerts its influence on iron and steel, causing them to become magnetic; that is, to have the power of attracting materials similar to themselves. There are two kinds of magnets:

1. Natural magnets.
2. Artificial magnets.

Natural magnets are found in the form of lodestone and certain iron ores, and are never used for compass adjustments, since they vary greatly in strength.

Artificial magnets are pieces of iron or steel to which magnetic properties have been imparted by various methods. Both types of magnets are possessed of the same property, namely, the power to attract and hold iron, or other, magnetic material.

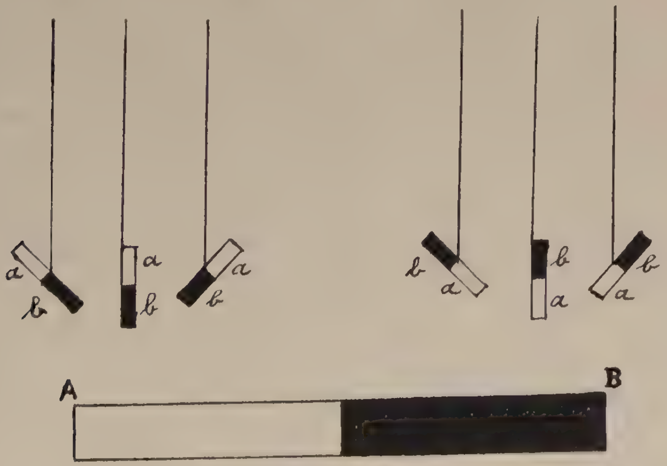
When a compass of steel containing a large proportion of carbon and particularly when it contains about 6% of tungsten, is rubbed with a natural magnet, or another artificial magnet, or is treated in certain other ways, it becomes itself a permanent magnet. The degree of performance depends on the composition of the steel and the manner in which it is stored. It has been found that the steel containing the above proportion of tungsten gives the most permanent magnets. Steel of the kind described is known as "hard iron" so far as magnetism is concerned, and pure iron is known as "soft iron."

All magnets have **two opposite poles** which are co-existent. The permanent magnet loses its magnetism in time, unless placed in contact with another magnet with opposite poles together. The artificial magnet may be made by any of the following methods:

1. Contact with another magnet.
2. Rubbing with another magnet.
3. Percussion in a magnetic field.
4. Passing into a coil through which an electric current is running.

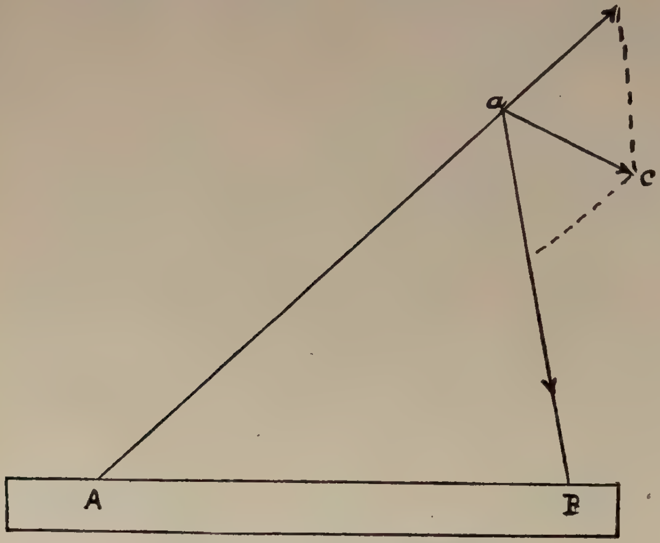
Any part of a magnet possesses a certain proportion of magnetism, but its great power is concentrated at two points near each extremity, these positions being known as the "Poles" of the magnet.

Artificial magnets have the same properties, and obey the same laws as the natural magnets, and in either, attraction is concentrated at the poles.



(FIGURE 45.) Magnets.

In order to demonstrate the **property of a magnet** it may be supposed that two artificial magnets ab and AB have been made, and that, a corresponds to A and b to B; then it is found that if the magnet ab be freely suspended, the pole A will repel the pole a and attract the pole b. In short, like poles repel, unlike poles attract one another. (Figure 45.)



(FIGURE 46.) Field of the Magnet.

For purposes of illustration, the magnet AB may be supposed to be acting on a solitary pole a. (Figure 46.) This pole is under the action of two forces—a force of attraction in the direction aB, and a force of repulsion in the direction Aa; the resultant of these forces is in some direction ac, and this direction is called the direction of the line of force of the magnet AB at the point a. Similarly, if a large number of points, such as a, are considered, the directions of the lines of force of the magnet AB will be as shown in Figure 46: the area over which the influence of the magnet is felt is called the field of the magnet.

If a small magnet ab, the influence of which on a large magnet AB is unappreciable, be freely suspended in the field of the magnet AB, it will take up a position along a line of force as shown in Figure 45.

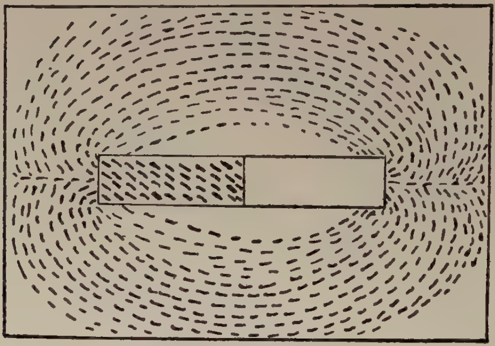
If the magnet ab be **freely suspended** at any place on the earth's surface, it will take up a definite position at that place; in North latitude one pole, a, will point downwards and roughly in the direction of the North Pole of the earth, Figure 45, at the Equator the magnet will be nearly horizontal, and in South latitude the pole b will point downwards and roughly in the direction of the earth. From this law and the one stated above, it may be concluded that the earth is a natural magnet, and that it has two poles, called the **North and South magnetic poles.** Thus it will be seen that the magnetism of the pole b, which is at the South seeking end of the magnet ab, is of the same nature as the magnetism at the North magnetic pole; so in order to avoid confusion when using the terms North and South, the magnetism of the earth at the North magnetic pole is called **Blue Magnetism,** and at the South Magnetic Pole, **Red Magnetism.**

Magnetism of the Pole a is, therefore, Red, and that of b, Blue.

It has been stated that the earth itself possesses the properties of a magnet, following the same laws as other magnets. **Its magnetic poles** do not exactly coincide with the geographical poles, one being situated N.W. of Hudson Bay, and the other in South Victoria Land. These poles are not points like the geographical poles, but are areas of considerable extent. The earth, being a magnet, has certain lines of force passing through it, and if any soft iron is placed in these lines of force, it will be affected by them and be magnetic.

The magnets used in compasses are always referred to as "**Needles**" and are permanent magnets usually saturated.

If a bar magnet be placed on a table with a sheet of white paper over it on which iron filings are sprinkled, it will be observed that the filings arrange themselves in the manner shown in Figure 47. If the paper be gently tapped the arrangement becomes more definite. It will be noticed that most of the lines start out from a point near one end of the magnet and go to a point near the other end in regular curves.

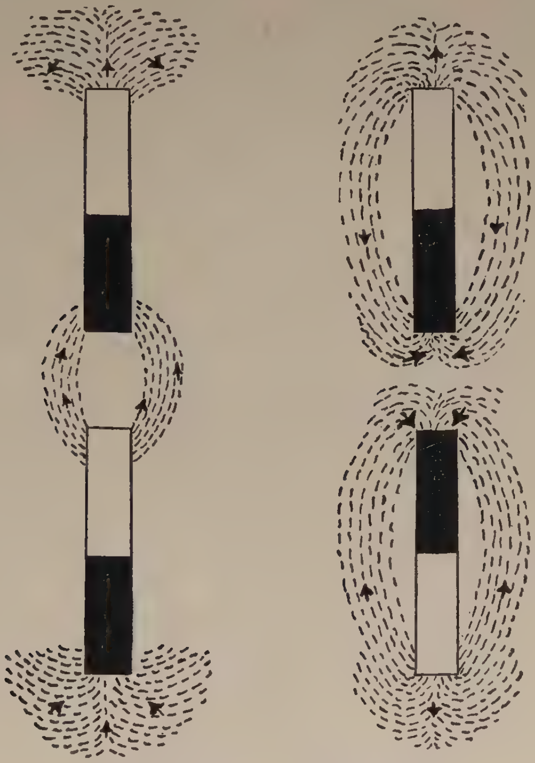


(FIGURE 47.) Induction.

Each particle of iron has become a magnet, and has a "**Red**" **end next to the** "**Blue**" **end** of that adjacent to it. If the magnet be removed, and the paper tapped, the filings will assume any position, showing that they have ceased to be magnets. While under the action of the magnet they are said to be magnetized by "**Induction.**" The directions taken up by the iron filings are called "lines of force." If the blue end of the magnet be placed near the red end of another in the same straight line, the lines of force take up the form shown in Figure 48.

If a small magnet be freely suspended above a strong bar magnet it will be seen to take up a position shown in Figure 45. Over the poles of the magnet the needle stands vertical, and over the center horizontal; this is called the "**needle zone.**"

It will be noted that the position assumed by the suspended magnet coincides with the line of force through the center of the suspended magnet.



(FIGURES 48, 49.) Lines of Force.

If the suspended magnet be made to vibrate it will be found that the **period of vibration** is less near the poles than when near the neutral zone, it being kept at the same distance away all the time. **The rate of vibration** is an indication of the strength of the magnetic forces.

If one of the magnets in Figure 49 is replaced it will be found that the filings arrange themselves in the same way. This is because the soft iron becomes a magnet by induction. Since the earth itself is a magnet, it influences all magnetic substances on it and induces magnetism in soft iron. It is clear, therefore, that **all "Soft" iron** on an airplane must be regarded as magnetic, with its polarity determined by the orientation of the airplane relative to the magnetic meridian.

> If a bar magnet be broken in half, it will be found that each half is a perfect magnet having its "Red" and "Blue" poles.

Attraction and therefore repulsion of magnetic poles varies inversely as the square of the distance.

The earth being a magnet obeys the same laws as a permanent magnet, and the compass needle at its surface is comparable to the suspended magnet over the bar magnet. Since we call the "Red" the North seeking pole, we consider the **Northern Magnetic Hemisphere to be "Blue" and the Southern, "Red."** It is usual in magnetic problems to consider only the fact of the Red Pole of a magnet, as the action of the Blue Pole is equal and opposite and so forms a couple.

A magnet has greater effect on a magnet needle or other object, end on, than when broadside on. Further, a magnet acts more powerfully when its direction is at **right angles** to the North or South line of the disturbed needle.

A permanent magnet will possess similar properties in any part of the world and in any direction in which it is placed, provided always that, if stowed with other magnets, the like poles are not together. Care should therefore be taken when stowing magnets to pack them with unlike poles together, i.e., Red to Blue. If this is not done and they are stowed Red to Red, or Blue to Blue; since a Red pole tends to induce an opposite, i.e. a Blue pole in adjoining magnets, the magnetism of each will be weakened. Magnets which it is desired to retain as such should never be heated, as their power is considerably reduced by any rise of temperature.

If a magnetized piece of hard iron be suspended by an untwisted silk thread at its center of gravity, it will point in any horizontal direction.

If the same piece of iron be magnetized by any of the methods described above, and freely suspended at any place under the influence of the earth's magnetism only, it will lie in the direction of the lines of force at that place, and that great circle of the earth in the plane of which the angle lies is the **magnetic meridian** of that place; the angle between the true meridian and the magnetic meridian of the place is the magnetic variation. Moreover, the magnet described above will take up a definite angle with the horizontal plane at that place; in **North latitude the red pole will point downwards** and roughly in the direction of the North Magnetic Pole of the earth; at the Equator the magnet will be North horizontally, and in **South latitude** the **blue pole will point downwards** and roughly in the direction of the South Pole of the earth.

In different latitudes the angle changes and is known as the **"angle of the dip."**

If those places on or near the Equator where the needle lies horizontally, are joined by an imaginary line around the earth, this line will represent the "Magnetic Equator." **Magnetic latitude** is indicated by the **angle** which a freely suspended magnet makes with the horizontal.

If a compass needle is allowed to settle under the influence of the earth's field only, and then a bar magnet is brought near it, the needle will be deflected. This is because the direction of the line of force at the compass, due to the bar magnet, is not in general the same as that of the horizontal line of force there due to the earth, so that the compass needle takes up a position between the two in the direction of their resultant.

Magnetism produced by electric current. Around a wire through which an electric current flows there is a magnetic field, the lines of force being concentric circles, the planes of which are perpendicular to the wire. If, however, two wires are laid together, having a current flowing in opposite directions, they will neutralize one another and the compass needle will no longer be affected thereby. This procedure is always carried out in the wiring of lighting sets, but magneto and switch wires are often laid singly, and the compass should not be placed in proximity to them.

Deviation. In addition to the earth's magnetism, the compass needle is subjected to the influence of various other forces which tend to divert the needle from pointing to magnetic North. One of these influences is known as deviation, and is due to the permanent and induced magnetism of the airplane. As the effect of this force is only constant for one direction of flight it is more difficult to allow for. Consequently the necessary allowances should be tabulated and posted up on the dashboard or other conspicuous place.

Deviation is the angle between the compass North, i.e.—the direction in which the compass needle is pointing—and the magnetic meridian. The allowance which it is necessary to make for deviation can be largely reduced by placing a system of artificial magnets in opposition to the magnetic forces causing deviation.

Causes of Deviation. If an airplane were built of non-magnetic material, the compass should have no deviation, but since hard iron is incorporated in its structure, a permanent magnetic system is set up having two distinct poles.

There is a further source of error from the soft iron which is sometimes found in an airplane, and may be quite suddenly **magnetized and de-magnetized.** In the process of constructing an airplane the iron and steel parts usually acquire an excess of magnetism, which, however, is soon shaken out, leaving a certain definite amount of permanent magnetism. The airplane will then act as a permanent magnet with its poles lying in some definite direction. When, therefore, a compass is fitted into an airplane, it is placed in the vicinity of the poles of a permanent magnet, which turns round with the airplane. Deviation is different on each of the points of the compass, and in order to discover and correct these errors, the airplane on which the compass is fitted must be turned to face each of these points, and the compass reading taken and compared with a compass unaffected by any local influences.

Some iron is neither entirely "Hard" nor "Soft." This iron becomes magnetized in the process of construction of the airplane, but after a time loses its magnetism. In a new airplane the compass of which has been adjusted by placing magnets in the adjusting tubes, a change of deviation may be expected; the compass should therefore be checked and corrected from time to time. This is especially necessary after a severe shock or crash, as this will tend to alter the magnetism and thus affect the deviation of the compass.

Soft Iron Errors. In an airplane there is naturally a certain amount of soft iron which is continually under the influence of the earth's magnetism, and its effect on the compass is of considerable importance, producing what are known as **quadrantal errors.**

It is often taken for granted that because the compass readings are correct on, say, North and East, there will be no deviation on NE; this is, however, not the case, because typical "Soft iron" error is never indicated when the airplane is headed on in to the cardinal points. "Soft iron" trouble may be detected on most airplanes and is sometimes serious, in that it may possibly amount to as much as 10° or 12° if the compass has been badly placed. **Quadrantal error** is confusing at first, as deviation of this kind is always alternately Easterly and Westerly on the successive quadrantal points. It may be produced by a mass of "soft iron," the effect of which is equivalent to a horizontal bar lying across an airplane. The induced magnetism in such a mass will always cause Easterly deviation when the airplane is headed N.E. or S.W., Westerly deviation on S.E. and N.W. Although it causes no deviation on any of the cardinal points, it will weaken the directive force, making a compass more sluggish on E. and W.

Every magnet has two poles, or points where the greatest energy is concentrated, distinguished as Red and Blue poles, because it is usual to paint artificial magnets in these colors. The Red pole of a permanent magnet is the one which would point North when the magnet is suspended at its centre and free to turn round. This end is also called the N. or marked end. Therefore, the end of a compass needle which points N. is the Red pole.

Like poles repel each other, and unlike poles attract each other. This can be proved on a compass needle, for if the red pole of a magnet be brought near to the N. or marked end, it will repel it, whilst the blue pole will attract it. Similarly, the S. end will be repelled by the blue pole, and attracted by the red.

It is therefore found from this experiment that the earth's magnetic pole is blue, because the Red Pole of the needle is attracted towards it.

The result is therefore to give the needle a North and South direction.

CHAPTER X.

THE AIRCRAFT COMPASS.

The Airplane Compass is a very delicate instrument, and is subject to so many influences which act upon it from outside and affect its behavior that unless the Navigator thoroughly understands the causes of its apparent instability, he will soon lose confidence in its accuracy and reliability, and consequently fail to take advantage of its indispensable assistance in Aerial Navigation. A superficial knowledge of the airplane compass is, therefore, of little use in aerial navigation. (Figure 50.)

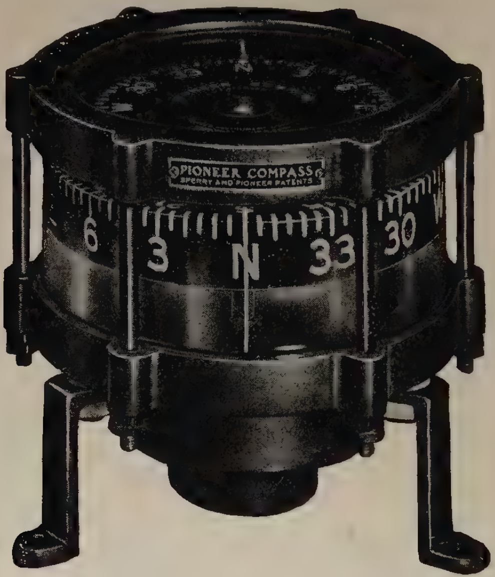
The magnetic compass is used for the purpose of orientation, for maintaining a course in a required direction, and for fixing the position of the airplane on a map or chart by means of bearings of distant objects. The Navigator, therefore, must thoroughly understand the nature of the forces which tend to prevent the compass needle pointing true North, and he must be able to counteract these forces or to make correct allowance for their effect.

There are various types of compasses. In Aerial Navigation the one generally used is the Magnetic Compass.

The Magnetic Compass consists of a number of small, highly magnetized needles mounted upon a central pivot in a bowl in such a manner that they are free to rotate in the horizontal. The bowl of an aero compass is filled with an alcohol solution, to prevent freezing and to damp the effect of vibration upon the needles, and thus reduce the oscillation caused thereby.

For the purpose of indicating the direction of any place in relation to the direction of the magnetic needle the compass card is installed. **The compass card** consists of a circular card attached to the magnetic needles, which is mounted so as to be free to rotate upon a central pivot. The outer edge of the compass card is graduated clockwise in degrees from 0° to 360°

in such a manner that the N.S., or 0° to 180° line of the card is parallel to the compass needle.



(FIGURE 50.) Magnetic Compass.

The compass bowl has a small mark internally on the forward side called the "**Lubber Line,**" and is so fixed in an airplane that a vertical plane through this mark and the point of suspension of the card is parallel to the fore and aft line of the airplane. The bowl moves about the compass card with the airplane as the latter is turned; thus the lubber line indicates the direction of the airplane's head in relation to the direction of the North seeking ends of the needles attached to the card.

General Description. The airplane compass is often subjected to considerable vibration and to stresses consequent upon flying maneuvers; it is, therefore, so constructed that the card, upon being disturbed, becomes steady quickly. The bowl is attached to the outer ring or frame by means of antivibrational spring attachments, so that any moderate shocks which the airplane experiences may not be transmitted to the compass. In order to allow for the expansion and contraction of the liquid in the bowl, **an expansion chamber** is fitted to the bowl, or alternately the bowl is designed to allow for this expansion. **The card** is supported by a metal stem from the bottom of the bowl; at the top of this stem is a jewelled cup, in which rests a pivot, either jewelled or iridium tipped, attached to the centre of the card. **The alcohol solution—pure alcohol with 6% distilled water**—with which the bowl is filled serves the dual purpose of reducing friction between the cup and pivot, and dampening the oscillations of the needle system. The bowl has a glass face, or cover through which the card as well as the "Lubber Line" may be seen. Above or below the compass, and exactly under or over the pivot, is a small box for carrying **small magnets** parallel to the fore and aft and athwartship lines, passing through the centre of the compass. These small magnets are reduced to correct errors in the compass readings due to various outside influences.

Maintenance and Fitting of Compass. The forces upon which the compass depends for its action are very small, and therefore anything which interferes with its accuracy must be reduced to a minimum if the instrument is to be depended upon. The constant vibration of the airplane will gradually impair the polish of the jewel and pivot, and this will be shown by the compass card "**sticking.**" This may be noticed when making an easy turn, when, if the pivot is not perfectly free, the card will turn with the airplane and will not indicate the change of course until a considerable angle has been taken. It will then commence to turn, perhaps with a jerk. Vibration sometimes displaces paint from inside of the bowl and card, which may lodge in the cup. This will cause pivot friction.

A heavy landing may damage the pivot, or in severe cases break it, therefore, the compass must have a thorough examination after any severe accident. To do this, place the airplane in flying position on any magnetic heading. Carefully note the reading of the compass. Place a correct magnet near the bowl at right angles to the needles, thus deflecting the magnet system through about 5°. Remove the magnet and wait until the magnetic system comes to rest. If it settles down in exactly its original position the compass is free from **pivot trouble,** i.e., friction. A small amount of pivot friction is often met with and can be eliminated by tapping the bowl with the finger. Should this not bring the magnetic system to its original position the compass should be immediately removed and the necessary steps taken for its repair.

Compass Liquid. Owing to the low temperature at great heights, **a non-freezing liquid** is necessary for the bowl. For this purpose an alcohol solution is used with about 6% distilled water. Dilution of the alcohol should be carried out at a temperature of 60° Fah. It must be well stirred up and allowed to stand for 24 hours before using. The bowl of the compass must always be kept properly filled with liquid, i.e., level with the bottom of the top filling plug when the compass is upright. When the compass gets very cold, as it will at great heights, the liquid contracts and a bubble forms at the top of the bowl, which will cause unsteadiness of the card. **These bubbles** should be removed at once, otherwise currents, set up by the moving liquid, are liable to cause the card to swing and thereby render the compass useless. To get rid of the bubble, the compass bowl should be first removed from its containing case and laid on its side, with the filling screw uppermost. The screw should then be removed and the solution dropped in, with a fountain pen filler or some similar article, until the bowl overflows.

The Effects of Changes of Speed and Course on a Compass. As the compass is required to show directions in the horizontal 'plane it is necessary to **overcome the effect of dip.** This may be done in two ways—by weighting the South seeking ends of the needle (in Northern Hemispheres), or by placing the point of support of the system a suitable distance above its center of gravity (i.e., making the magnetic system pendulous). Actually a combination of both methods is usually adopted in modern compasses, and as a result the tilt of the system out of the horizontal will never exceed 3° in any part of the world. In the Northern Hemisphere the center of gravity of the system lies always a small distance South of the vertical through the pivot.

Suppose an airplane flying East increase speed. The inertia of the magnetic system acting at the center of gravity **causes it to lag** and the system turns in a clockwise direction. Thus, Easterly deviation is caused. A decrease of speed while flying East causes Westerly deviation. The deviations so caused are only temporary; the deviations set up in this way are said to be due to speed error. The maximum effects are seen on Easterly and Westerly courses; speed error has no effect on Northerly or Southerly courses.

Northerly Turning Error. This causes temporary deviations when an airplane is steeply banked. During a correctly banked steep turn the plane of the needles is parallel to the floor of the airplane. Then the tendency is for the North seeking poles to be drawn downwards in the tilted plane during a turn from North. The result is that the compass card does not register the turn correctly. Three possible effects may be observed. If the compass card turns more slowly than the airplane, a smaller turn than has actually been made is registered by the instrument. If the rates of turning of the card and airplane are equal, no change of course is indicated. A turn in the wrong direction is indicated by the compass when the card turns more quickly than the airplane. The effect of the Northerly Turning error will be seen in any type of compass, and each type has its individual behavior.

The effects of speed error and Northerly Turning error may be summarized as follows:

> Increase of speed causes Easterly deviation on Easterly courses, and Westerly deviation on Westerly courses.
>
> Decrease of speed causes Westerly deviation on Easterly courses, and Easterly deviation on Westerly courses.

A change of course from N. to E. or from S. to E. causes **Easterly deviation.** A change of course from N. to W., or S. to W. causes **Westerly deviation.** Deviations due to alterations of speed and course may be set up to some extent on any course, excepting that speed error cannot arise on Northerly or Southerly courses.

Liquid Disturbances. A series of quick evolutions is liable to disturb the compass liquid, which may cause the card to be carried round in the direction of the swirl; but provided the bowl has been completely filled, the "Carry off" should not be serious, and the card will settle again in a few seconds unless the magnetic control is very weak.

Laying out a Swinging Base. A swinging base can be laid out quite accurately by use of the landing compass. This is a small portable liquid filled compass designed for mounting upon the tripod with which it is used. The card is graduated to single degrees and is read through a magnifying prism. A sighting device consisting of a slot and hair line allows very accurate bearings to be taken.

The swinging base should be laid out carefully on the airport, the following points being carefully observed:

1. The base should be level.
2. It should be free from any local magnetic influence, such as hangars, railway lines, electric cables, wires, fences, etc.

To check this, bearings of distant objects are taken from the site by landing compass and compared with magnetic bearings taken from a map of the district. The two sets of bearings will agree if the site is free from the aforementioned influences.

Another method, is to set up one landing compass on the site of the base and the other a distance of about 200 yards away. Bearings are taken from each instrument to the other one, and, if the magnetic conditions of the site are satisfactory, one bearing will be the reciprocal of the other. The second bearing compass should be moved round a circle with the first as center and eight or ten readings taken in all from each compass.

The base is marked out by setting up a landing compass and marking on the ground a circle of which the compass is the center.

A suitable radius is twenty feet. Bearings are then made on N., N.E., E. and other cardinal and quadrantal points, and a peg driven in on the circumference of the circle to correspond to each of these bearings. These pegs should now be joined up by lines painted on the concrete surface of the base.

The correctness of the marking of the base may be checked easily by driving uprights into the ground at the extremities of the lines and taking the bearings of the pairs of uprights in transit. Any errors will be apparent at once.

Swinging the Compass. The process of adjusting the compass and subsequently determining the deviations remaining in it when fixed in the airplane, is known, colloquially, as "Swinging the Compass." For this purpose a **swinging base is used.** This consists of eight radial lines marked on the surface of the ground. These lines intersect at the center, and their directions indicate the positions of the cardinal and quadrantal Magnetic points. It is thus possible to head the airplane by means of those lines towards any of the eight points, and the difference between the reading of the compass and the magnetic bearing of the airplane is deviation.

Preliminary to swinging the airplane for compass adjustment, it should be first fully equipped and loaded as normally flown, and should then be wheeled into position on the swinging base.

> The centre of the compass should be directly over the center of the swinging base, and the airplane should be placed in flying position with her nose pointing to the North.

Two plumb lines should now be fixed, one to the propellor boss and one to the tail skid, in such a manner that the bobs hang just clear of the ground, care being taken to ensure that the line adjoining them is coincident or parallel with the axis of the airplane. With the help of these plumb lines, the airplane can now be accurately aligned on end of the magnetic points indicated by the radial lines marked on the surface of the base.

As soon as the airplane has been properly aligned and levelled, the compass bowl should be so adjusted that:

1. It is perfectly upright when the airplane is in flying position.
2. ''Lubber Line'' is exactly parallel to the fore and aft line of the compass.
3. The magnet holder is empty and in its correct position immediately above or below the pivot of the compass, with its slots pointing in the fore and aft and athwartship direction.

The card should then be tested to ensure that it swings freely. This may be done by deflecting the needle 20° to 30° with a magnet, and observing if it comes to rest in exactly the same point again.

The first correction to the compass should be made when the machine is heading on one of the cardinal points, usually magnetic North. Any deviation should be eliminated as far as possible by means of compensating magnets placed in the athwartship receptacles of the magnet holder, i.e., at right angles to the magnetic meridian. The operation is then repeated on the East point, and this time the magnets, being always placed at right angles to the magnetic meridian, will be inserted in the fore and aft slots instead of athwartships. If the compass has been accurately fitted in the airplane, the adjustments that have been made on North and East should give accurate readings on the reciprocal headings, South and West.

In actual practice, it is rarely found possible to eliminate errors entirely, and the compass should therefore be so adjusted as to show an equally small deviation on each, of the opposite cardinal points, i. e., North and South, East and West.

The following typical example will help to explain this:

> After correction, the reading on East point was 91°. On the airplane being headed West, the compass is found to read 263°. The final adjustment must be made, therefore, so that the readings are approximately 87° on East point and 267° on West point. This will, of course, necessitate a re-arrangement of the compensating magnets on the fore and afts lots, and will naturally affect the readings on the points previously checked. Fresh readings must, therefore, be taken on these headings. The deviation of the cardinal points having been measured, the next step is to take readings on the four quadrantal points. No attempt, however, must be made to correct any error found on these headings.

Although the compensating magnets can only be used on the cardinal points to correct the permanent or subpermanent magnetism in the airplane, it is always necessary to take compass readings on the quadrantal points also, in order to ascertain the "soft iron" influence. Where extreme accuracy is required, but only for very special work, readings are taken on every 15°.

Correcting Magnets. Compensating magnets are often too strong, or the slots in the magnet holder may be too close together, to obtain the required fine adjustment. In order, therefore, to get accurate and well-balanced readings, it is necessary to resort to various other expedients.

The strength of a magnet may always be reduced by snipping small pieces off the end, or, again, a weak magnet effect may be obtained by opposing the poles of two magnets placed in the same or different slots.

If the first method is resorted to, the magnet must never be reduced less than ¾ the length of the slot in which it is placed.

Deviation. The removal, addition or alteration of any magnetic substance in the compass will necessitate its re-adjustment; but, in addition to this, the readings should be checked at least once a month and any change in deviation should be corrected. If there are only minor errors, the necessary alterations should be made on the deviation card. Changes in local magnetic conditions in airplanes are more frequent than is generally supposed.

Where a number of magnets have been placed together in the same tube, they are liable to destroy each other's magnetism, and lose some of their original strength. These causes of deviation make it possible for a compass to show considerable errors without any alterations having been made in the surrounding fittings.

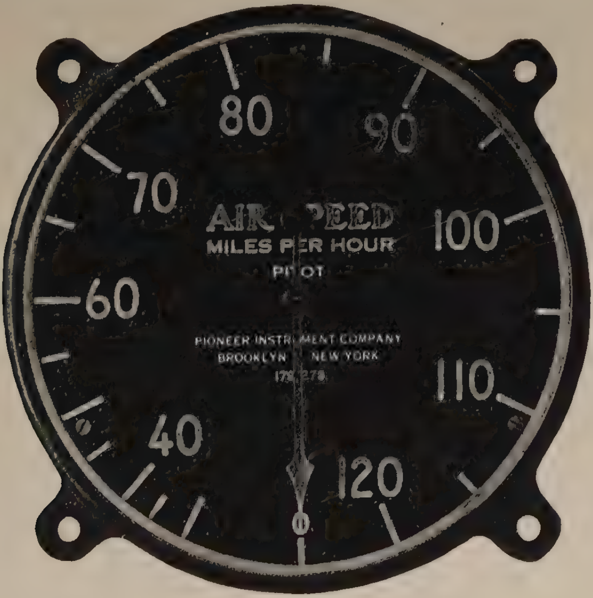
The following points should be observed when a compass is being adjusted:

1. The compensating magnets should always be placed at right angles to the magnetic meridian, i.e. when the airplane is headed South or North, the slots athwartship should be used; when the airplane is headed East or West, the magnets should be placed in the fore and aft slots.
2. No attempt should be made to correct deviation on any of the quadrantal points. It is impossible to eliminate this deviation with ordinary compensating magnets.
3. The error on the cardinal points should invariably be balanced, that is, the compass should be adjusted so that the deviation is equally small on each of the opposite readings—North and South, or East and West.
4. Any re-arrangement of the magnets will necessitate fresh readings being taken on all previously tested headings.
5. After adjustment the magnet holder must be carefully locked.

CHAPTER XI.

INSTRUMENTS.

Air Speed Indicator. This consists of the Pressure Head and the Indicator proper which is mounted in the cock-pit, the two separate parts being connected by metal tubes with rubber joints. The pressure head is fitted to an outer strut so that it may be out of the airscrew slip-stream: it must be fixed so that it points straight ahead when the airplane is in normal flying position. The pressure head consists of two tubes placed one above the other and clamped together, one being called the pressure tube and the other static tube. The pressure tube is open to the air: the static tube is closed at its forward end but contains a number of small holes along the side. The pur-



(Figure 51.) Air Speed Indicator.

pose of these holes is to ensure that the pressure inside the tube is the same as the atmospheric pressure at the height at which the airplane happens to be. (Figure 51.)

The air speed indicator only **gives absolutely correct readings** at ground level: owing to the decrease of density of the air with height the air speed indicated by the instrument is less than the actual air speed. Correct speed can be obtained approximately by adding 1.75 per cent of the indicated air speed for each 1,000 feet in altitude. Thus, if an airplane be flying at 10,000 feet at an indicated air speed of 80 miles per hour, the actual air speed is 94 miles.

Altimeter. Owing to the imperfect elasticity of the vacuum chamber and the spring, the altimeter does not immediately record changes of height. If the height is suddenly changed by a 1,000 feet the pointer will only move slowly and about one minute will elapse before the correct height is shown.

> "On account of this lag the altimeter will read low when ascending and high when descending."

The altimeter requires little attention, provided the holes at the back of the case are kept clear. Although the mechanism is delicate the instrument will continue to work accurately for long periods, so long as it is preserved from shocks or excessive vibration. A leak in the vacuum chamber or damage to the mechanism will render the instrument unserviceable.

(Bearing Plate.) Service Type. The instrument consists of three concentric rings which can be turned relatively to each other. The middle ring constitutes the base plate and is furnished with a bracket which will fit into a metal shoe mounted on the airplane. The inner ring is marked in graduations of 1° from 0° to 360°. The outer ring carries a hinged height scale marked from 500 to 2,500 feet, fore and back sights, and two diametrical celluloid lines. Two metal shoes are supplied for fixing the airplane in order that the instrument may be used on either side. The Bearing Plate must always be fixed in the airplane with the Lubber Lines parallel to the fore and aft axis of the airplane.

The instrument has three uses:

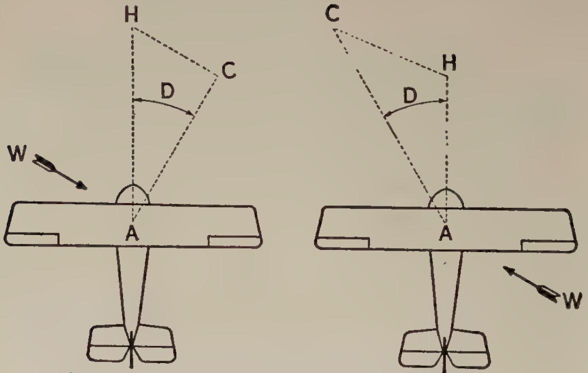
a. Taking Bearings.
b. Indicating Drift.
c. Obtaining Ground Speed.

The magnetic bearing of an object may be taken in the following way.

1. Set the inner dial with the graduations representing the magnetic course of the airplane opposite the lubber line. Turn the sighting arm until the object is seen in the line of sight; the magnetic bearing can then be read on the inner dial. Alternatively, the inner dial may be set to zero, and a bearing taken relative to the head of the airplane. Magnetic bearing may be obtained from this by adding angle indicated on the bearing plate to the magnetic course of the airplane at the instant the bearing was taken. This latter method will generally be the more accurate as it is easier for the pilot, by means of a simple signal, to read the course of the plane at the instant the observer takes the bearing, than it is for the observer to take the bearing at the instant the airplane is on its course, as indicated by the pilot.
2. The instrument can also be used **for measuring angles.** When used for this purpose the inner dial must be set to 0° and the bearing plate used as when taking bearings. Then the angle between any two objects will be the difference in degrees between the two readings on the graduated arc obtained by sighting on the objects.
3. **To use as a Drift Indicator.** Set the inner dial to zero, look vertically downwards through the open centre and turn the outer dial until objects on the ground or surface of the sea appear to pass along the diametrical lines from end to end. Read off the difference in angle to starboard or port between the zero of the instrument and the central diametrical line. This gives the angle of drift in degrees.

4. **To obtain Ground Speed.** Set the sight bar on Height Scale to the height of the plane above the ground over which the airplane is flying. Align the eye-hole sight with the fore-sight on any object which lies in the actual track and when alignment is vertically below the observer, as indicated by the rear sight coming into alignment between the eye-hole sight and the object, stop the watch. The plane has then passed over a certain distance in the time indicated by the stop watch and from this the ground speed can be calculated.

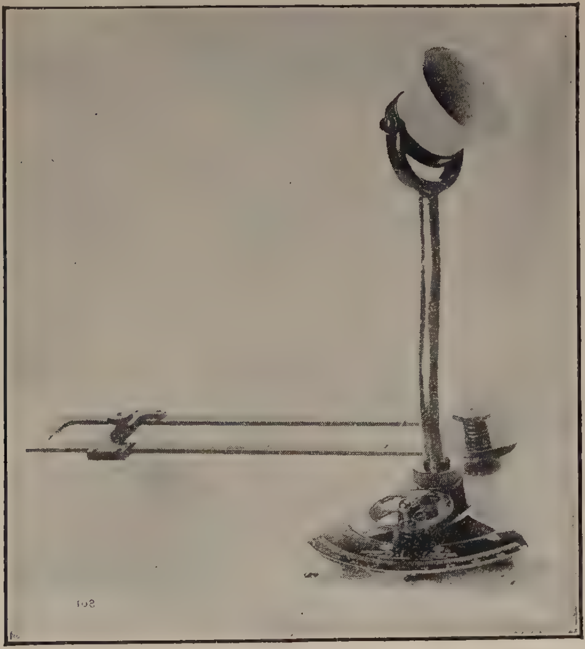
A Drift Indicator is a necessary auxiliary to a compass, if accurate aerial navigation is to be accomplished. As is well known, an airplane may be headed in one direction yet follow a course in another direction. The difference between **heading** and **course** is the **drift angle.** This is illustrated diagrammatically in Figures 52 and 53. The airplane A is headed in the direction H, but because of the side wind W, actually travels toward C. The angle D is the drift. In order to "make good" the desired course, it is imperative that the pilot (or navigator) know the drift angle so that he may calculate the heading and that the airplane be steered accordingly.



(FIGURES 52, 53.) Drift Angle.

The only practical way of ascertaining the drift is by observation of the ground, and a Drift Indicator, or Drift Angle Meter as the instrument is sometimes called, is used for this purpose.

This instrument may be mounted anywhere on an airplane where it affords an unobstructed view downward (vertically if possible, but at an angle if more convenient) and where it may be conveniently observed and manipulated by the navigator. The instrument is supported by a Mounting Bracket from which it may be quickly removed. It is sometimes advisable to install two or more brackets and to transfer the instrument from one to the other, according to the direction of drift or the convenience of the navigator. The mounting bracket must be



(FIGURE 54.) Drift Indicator.

installed with its center line either fore-and-aft or athwartship. Any error in its location will cause a corresponding error in drift readings.

To obtain the **drift angle** with the Speed and Drift Indicator, first make fast the support for the eyepiece in a position which will be convenient for the user and also allow him to make his observation properly. It is not necessary that the eyepiece be directly over the wire. The operator then sights through the eyepiece at the drift wire and the ground below. The vane is now rotated so that objects on the ground or sea appear to travel along the drift wire. This means that the drift wire is now in line with the course being made good in respect to the ground. The drift angle, or angle between the heading of the plane and the course being made good, can now be read from the scale.

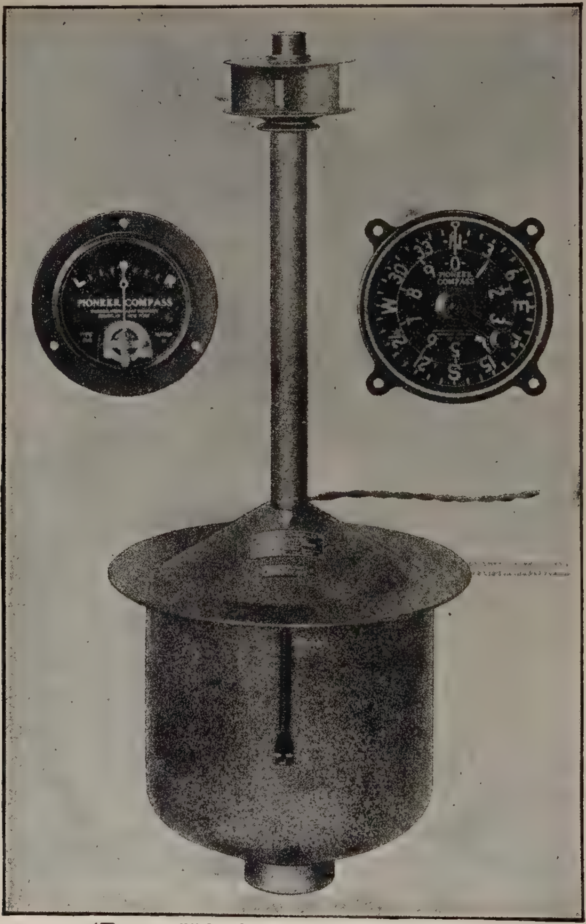
To obtain the **Ground Speed,** the vane is left in position corresponding to the drift angle and the slider is moved along the vane until the cross-wire is at the figure corresponding to the altitude of the plane above the ground which it is flying over. The altitude of the country which the plane is flying over must be subtracted from the altitude of the plane above sea-level to obtain the altitude of the plane above the ground. Looking through the eyepiece, the distance seen on the ground is that marked on the side of the vane—either one-tenth mile, four-tenths mile, or one mile. The scale which reads "One mile for altitude in thousand feet" can also be used for "One-tenth mile for altitude in hundred feet."

With a watch, the time of passage of an object from one wire to the other is noted, and reference to a table which is furnished with the instrument gives the corresponding speed in miles per hour. For example, let us assume it is desired to obtain the Ground Speed while flying at an altitude of 4,000 feet above the ground. First move the slider along the vane and set the cross-wire at the figure 4, which is on the scale marked "Four-tenths mile for altitude in thousand feet." Assume the stop-watch shows the time of passage of an object on the ground between the fixed cross-wire and the movable cross-wire to be 12 seconds. Reference to the conversion table will quickly show the speed to be 120 miles per hour. But if the table is not at hand, simple arithmetic will do. The distance seen on the ground between the cross wires was 4/10 mile and the elapsed time 12 seconds. This is at the rate of 1 mile in 30 seconds, 2 miles per minute or 120 miles per hour.

The **Pioneer Speed Timer,** is a special stop-watch graduated to read directly in miles per hour. The Speed and Drift Meter may be calibrated for nautical miles or kilometers instead of statute miles. When so calibrated the Speed Timer gives knots or kilometers per hour, according to the Speed and Drift Indicator with which it is used. The conversion table furnished with the instrument may also be used for any units of distance.

The Pioneer Earth Inductor Compass is a remote indicator of direction. It is related to the ordinary magnetic compass only in its use of the earth's magnetic lines as a directive base.

There is no physical similarity between the two types of compass. The Earth Inductor Compass comprises three principal units. That which reacts with the earth's field and therefore corresponds to the magnets of an ordinary compass, is the Inductor Generator. This resembles an ordinary electric Generator, except that it has no artificial field. It has an armature, commutator and brushes and produces electric potential by reaction with the earth's field. As in the case of any electric Generator, the potential depends upon the angle between the brushes and the field. In the Earth Inductor Generator, the brushes may be orientated about a vertical axis, so that they may be set in any angular relation to the fore-and-aft line of the airplane. They may therefore be turned in relation to the earth's field, either independently or with the airplane. As in any Generator, turning the brushes in relation to the field discloses two positions of maximum potential and two positions of



(Figure 55.) Earth Inductor Compass.

zero potential. In the Earth Inductor Compass, use is made of one of these positions of no potential. (Figure 55.)

The second unit is the Direction Controller. This carries a dial similar to an ordinary compass card and has a crank by which this dial may be turned to any position. There is a mechanical connection between the Controller dial and the brushes of the Generator, so that the angular position of the brushes is indicated upon the Controller dial. (Figure 55.)

The third unit of the compass, **the Steering Indicator,** is a sensitive zero-center galvanometer, the dial of which is marked LEFT and RIGHT. The Indicator is electrically connected to the brushes. (Figure 55.)

When the compass is installed, the connection between the Controller and the Generator is made such that when the airplane is headed in the direction indicated on the Controller, the brushes will be in a position of zero potential. The Steering Indicator hand will therefore remain in the center of the dial. If the airplane is turned to the right, the Generator brushes will be turned in relation to the earth's field and the Generator will produce electricity of the proper sign to cause the **hand of the Steering Indicator to move to the right, showing the pilot that the airplane has turned to the right.** Turning the airplane to the left will put the Generator brushes into such position that electricity of the opposite sign is generated, causing the Steering Indicator hand to move to the left.

As the compass is ordinarily used, the **desired heading** is set upon the dial of the Controller and the airplane is then turned until the Steering Indicator hand comes to zero. Turns to the right or left away from this heading will cause the hand to move right or left. When it is desired **to change heading,** the Controller dial is cranked to a new position and the airplane again turned to bring the Steering Indicator hand to zero.

The Earth Inductor Compass offers many advantages over the ordinary Magnetic Compass, particularly for use on aircraft. It is much easier to follow the **hand of the Steering Indicator** than it is to keep a certain mark on a swaying compass card opposite the lubber-line. The outstanding advantage, however, is the disassociation of the direction-responsive element and the direction-indicating units. In the ordinary Magnetic Compass, these cannot be separated and in order that the pilot may see his compass, it is frequently necessary to place it in a position where it is subject to strong local magnetic fields. With the Inductor Compass, on the other hand, the Generator may be placed in a position which is practically free from magnetic disturbance, while the Steering Indicator is placed in the best position for observation by the pilot. The Controller may be operated either by the pilot or by a navigator.

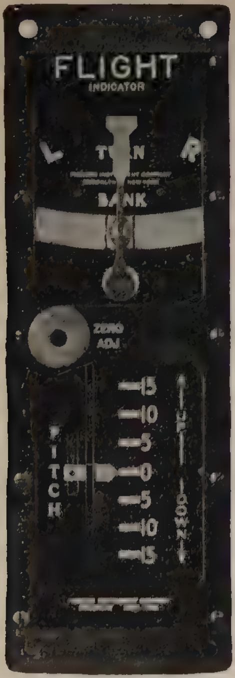
The Pioneer Earth Inductor or Compass is the invention of Morris M. Titterington, Chief Engineer of the Pioneer Instrument Company.

It was used by U. S. Army on their Round-the-World and Pan-American flights, on Commander Rodgers' Hawaiian flight, Commander Byrd's North Pole flight, on the Trans-Atlantic flights of Lindbergh, Chamberlin and Byrd, and on the flight of Brock & Schlee from New York to Tokio.

The Flight Indicator. An airplane is controllable about three axis. It turns about its rudder axis, banks about its longitudinal axis, and pitches about its lateral axis. In normal straight flight the rudder axis is vertical and the other axis are horizontal.

An airplane is controlled in its movement about these three axis by the pilot's manipulation of the rubber-bar (or pedals) and the "stick" (or wheel), operating the rudder, ailerons and "flippers." Movements of all three controls are frequently simultaneous, and to some extent are interrelated, but each may be considered separately as affecting the motion of the airplane about one axis: the rudder turning the ship about the rudder axis, the ailerons banking the plane about the longitudinal axis and the flippers pitching it about the lateral axis.

When the ground can be observed it is easy for the pilot to keep track of his maneuvers about all three axis, but when flying blind in fog or clouds, or at night, it is necessary to use an instrument to replace the visible ground reference. Pioneer Flight Indicators, of two types, answer this requirement. (Figure 56.)

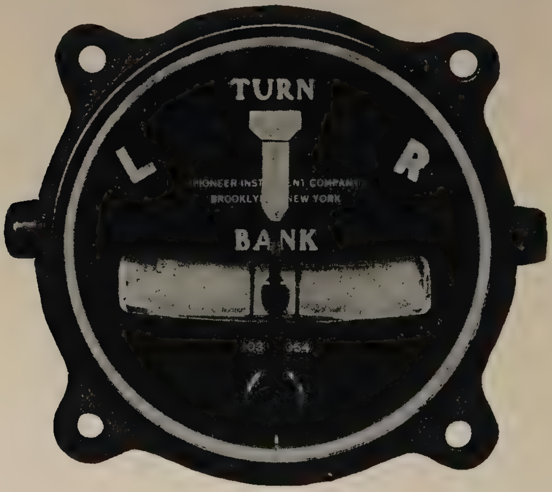


(Figure 56.) Flight Indicator.

Two of the elements of the Flight Indicator, and these are identical in both types, are indicators of turn and bank, which are now quite familiar to everyone through their general use in the Pioneer Bank and Turn Indicator.

The Turn Indicator shows to the pilot if his airplane is turning about the rudder axis, and the approximate rate of the turn. It does not show turn about the vertical except to the extent that the rudder axis is vertical, but it always tells the pilot precisely what to do with his rudder control to maintain or resume straight flight. If the hand **goes to the left, push on the right foot.** If it goes to the right, push on the left foot. (Figure 57.)

The Bank Indicator shows if the airplane is laterally level in straight flight, or if it is correctly banked on a turn. In both cases the ball remains in the center. Whether flying straight or turning, the ball shows the "low" wing—that is, the wing which is lower than it should be. (Figure 57.)



(FIGURE 57.) Turn and Bank Indicator.

(On an under-banked skidding left turn the ball goes toward the right, showing that the right wing is too low, although it is higher than the left wing.)

Whether flying straight or on a turn the Bank Indicator shows the pilot precisely what to do with his ailerons. When the ball goes **to the right** move the stick (or the top of the wheel) **to the left.** When the ball goes **to the left,** move the stick, **to the right.**

It is in the third element that the two types of Flight Indicator differ. One, type 82E, offers as a guide to movements of the airplane about its lateral axis a gyroscopically-controlled fore-and-aft inclinometer. This differs radically from a simple pendulous inclinometer. The latter is adversely affected by longitudinal accelerations of the airplane, and may frequently show an angle which is only a fraction of the actual inclination to the vertical. However, pitching of an airplane is accompanied not only by fore-and-aft accelerations, but by angular motion about the lateral axis, and this motion is translated by the gyroscope into an angular displacement of the hand just opposite to that which would be caused by acceleration. As a result the changes in longitudinal angle are magnified instead of obscured.

The Pitch Indicator does not show movements about the lateral horizontal, except to the extent that the lateral axis of the airplane is horizontal. A plane may descend in a steep spiral and still be "climbing" about its lateral axis. Regardless of the altitude of the plane, the Pitch Indicator shows the pilot precisely **what to do with his flippers.** If the hand goes up, push the stick (or wheel) forward. If it goes down, pull the stick back. (Figure 56.)

In the other form of Flight Indicator, type 322, we resort to a secondary means of indicating the proper fore-and-aft control. The primary result of moving the control stick forward or back is change of longitudinal angle. The secondary result is loss or gain of altitude. For some purposes it is of first importance to maintain a certain altitude, for others loss or gain of height is of more consequence. **Here a Climb Indicator** is employed as the longitudinal control element. This unit differs from all those previously discussed, as its indications are relative to altitude and not to motion about only one axis of the airplane. However, the normal method of changing altitude is by operation of the longitudinal control, and in all usual flight altitudes the indications of the Climb element relate directly to the fore-and-aft movement of the control stick. If it is desired to maintain level flight, when the Climb hand goes up push forward on the stick (or wheel). When the hand goes down, pull back.

In addition to its function as a flight controller, this unit operates as a **complete Climb Indicator** and it may be used in securing maximum rate of climb, minimum rate of descent, or any desired rate either up or down.

The gyroscopes in both types of indicator are operated by the vacuum secured from Venturi Tubes. Flight Indicator, type 82E, having two gyroscopes, requires a larger Venturi. For air speeds up to 110 miles per hour use type V3F Venturi Tube, at higher speeds type V74B. With the type 322 Flight Indicator use Venturi V3F at 75 m.p.h or type V74B above this speed. The Climb Indicator of the type 322 instrument requires an auxiliary air tank.

INSTALLATION

Indicator. A hole is cut in the instrument board, and the indicator fastened securely in place, as in the mounting of any other instrument. The indicator should be mounted so that the dial is vertical, and the ball in the center of the tube, when the aircraft is in normal flying position. If the indicator is mounted in the instrument board before the board is installed in the ship, care must be taken to have the indicator square with the board, and to install the board level in the airplane.

Venturi Tube. The Venturi Tube should be mounted on the side or top of the fuselage or upon a strut, as close as is convenient to the instrument board and where it will be kept warm enough to prevent freezing. It must be placed in a position where it receives an unobstructed flow of air. It is advisable to mount the tube in the slip-stream to insure that the indicator will be in full operation before taking off. Mount the tube so that the arrow on the name plate points forward.

Air Tank (for type 322). Install the auxiliary tank in any convenient location within 3 feet of the indicator.

Connecting Tubing. For connecting from the Venturi Tube to the Indicator a length of ¼″ copper or brass tubing should be used. The tubing should be run as straight as possible, avoiding bends of small radius.

After cutting the tube to the right length, the nuts and cones of the soldering unions should be removed from both the Indicator and the Venturi Tube. Slip the nuts over the tube (back to back, threads out), and solder a cone on each end. Be sure that no solder runs out on the cone seat as this will spoil the joint. Blow the tubing clear of all dirt, put it in place, and screw up the nuts at each end.

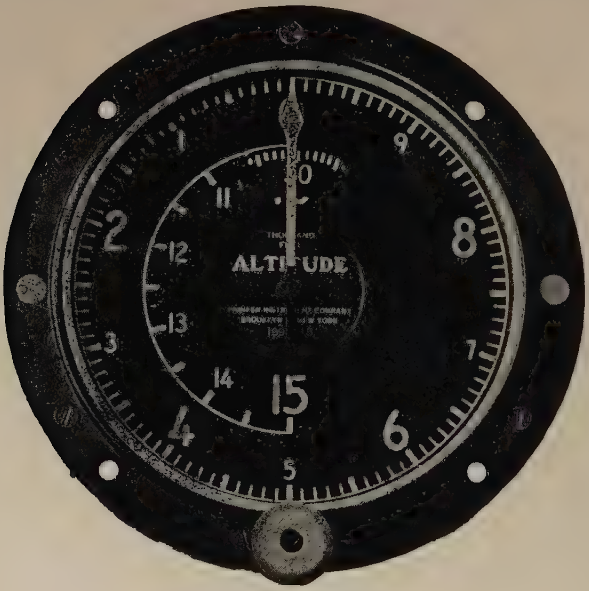
For type 322, connect tank to indicator with the small tubing supplied. Coil up the excess.

Care. The Venturi Tube should be inspected periodically to see that it does not become stopped up by anything blowing into it. Union nuts should be kept tight.

Warning. Do not, under any consideration, take the Flight Indicator apart. It is assembled at the factory by skilled instrument makers, and if damaged should be returned to them for repair.

The Pioneer Altimeter, used to determine the height of aircraft, is simply a refined aneroid barometer, on which the dial is graduated in units of height above the ground instead of in units of pressure. It is further distinguished from a barometer by the fact that its dial may be rotated so that any elevation above sea-level or any barometric pressure may be taken as zero. (Figure 58.)

As a result of many experiments, the average relation between altitude and barometric pressure has been determined. These figures have been published by the Bureau of Standards and have been officially adopted by the U. S. Army and Navy. All Pioneer Altimeters are graduated to this standard.



(FIGURE 58.) Altimeter.

It must be remembered that these are average figures, and are not exactly correct except under "standard" atmospheric conditions. For example, an altimeter **will usually read lower** than actual altitude in the summer and higher in the winter. This is due to atmospheric temperature and not to any error in the instrument.

Altimeters are also subject to errors due **to changing barometric pressure** during a flight. If the barometer falls, the altimeter will read high; if the barometer rises, it will read low. This characteristic may be turned to good account and the instrument used as a weather guide. If the altimeter has been set to zero before leaving the airplane at night, its reading in the morning, if below zero, indicates fair weather, and if above zero, approaching storm. The distance off zero is a rough indication of the intensity of the change to be anticipated. In judging weather, it is of course necessary to take account of many factors besides barometric pressure, but an altimeter can be very helpful if used wisely.

Pioneer Altimeters are supplied with **a barometric scale** which increases their usefulness considerably. A pilot may secure information regarding the barometer reading at the field of his destination and then, on taking off, set the zero of his altimeter dial to correspond with the barometric pressure of his destination. The altimeter will then read altitudes above the field to which the pilot is headed.

Pioneer Altimeters are the result of extensive research and painstaking development over many years. They are made with great care by highly skilled instrument makers. Due to the selection of proper materials, and by unusual refinement of design, **the "lag" has been reduced** almost to the vanishing point. (By "lag" is meant the difference in reading when ascending and descending.) Most altimeters function accurately when climbing, but where the readings are much more important, in descending, many **instruments are woefully unreliable.** It is not uncommon to find an altimeter reading 500 or 600 feet after the airplane has returned to the ground. But this never happens with a Pioneer Altimeter. The hand is guaranteed to return to within 0.020 (one-fiftieth) of an inch of zero, after descending from any altitude. The importance of this, when coming down through rain, snow or mist, and at night, can hardly be overestimated.

CHAPTER XII.

ICE ACCUMULATION ON AIRPLANES *

Meteorological factors affecting airplane flying fall into two main classifications, those which prevent or stop flying and those which affect flying or navigating while flying. The main factor which prevents flight is undoubtedly the accumulation of ice upon the various exposed surfaces of the plane. Its quick action and the small chance of the plane being rid of the trouble by mechanical means gives to this factor grave importance, and the limited character of the experiences of those pilots which have found themselves caught by icing-up weather has resulted in a rather imperfect apprehension of just what goes on during the action known as icing-up, or the accumulating of ice-coats on the plane's surfaces. These ice barnacles threaten a forced landing in so certain terms that any but the best trained pilots should be cautioned against flights through clouds or rain at moderate altitudes above ground where the temperature is between 15 and 40 deg. F.

The pilots who man the planes of the transport line between New York and Cleveland meet as much ice as any in this country; their experiences are varied but from their reports and the theoretical considerations which best fit the facts gathered from them several general truths emerge. This airway has such conditions as a result of at least three factors;

a. The moderate altitude of the mountainous region,
b. The proximity of the Lake Region to the northwest,
c. And the situation on eastern side of a great continent which is a ''cold'' reservoir in the winter months.

What then is the action of ice upon the plane? From a variety of opinions it appears that the ice-barnacles affect the efficiency of the plane in three ways, perhaps more. (Figure 59.) **The parasitic resistance** offered by struts, wires, outside fixtures of various sorts and the wings themselves is immensely

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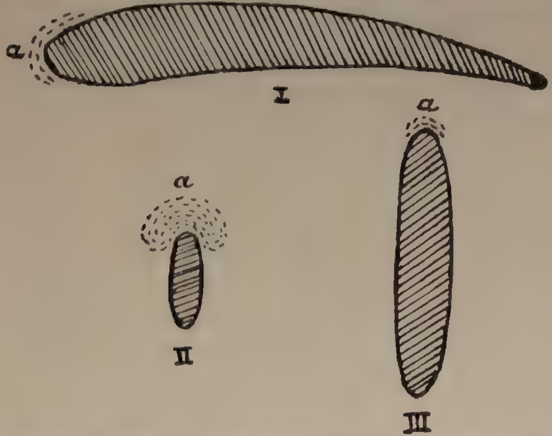
* Excerpt from the weekly magazine "Aviation."



"I"—cross section of Clark Y type of airfoil. "II"—cross section of streamline wire. "III"—cross section of wing strut. In all three drawings "a" signifies ice accumulation.

(FIGURE 59.)

	Uncoated	Coated to assume ½ in. on (1), (4) and (5) and ⅝ in. on (2), (3)	
(1)	1,347 lb.	27.22 lb.	(ratio 1/20)
(2)	14.900	197.60	(ratio 1/13)
(3)	8.649	176.10	(ratio 1/20)
(4)	1.537	20.10	(ratio 1/13)
(5)	1.755	22.95	(ratio 1/13)
Tot.	28.19	443.97	(ratio 1/16)

Table showing approximate resistance developed by iced and un-iced wires. Figures based upon an airspeed of 105 mi/hr, and resistance for streamlined wires, and for cylindrical hard smooth wires, for uncoated and coated conditions respectively.

(1) Stabilizer wires total length 19 ft., .072 in. thick.
(2) Flying wires total length 110 ft., .132 in. thick.
(3) Landing wires total length 98 ft., .090 in. thick.
(4) Center section brace wires length 14 ft., .112 in. thick.
(5) Incidence brace wires 16 ft., .112 in. thick.

The ice-coat is neither hard nor smooth, and the figures for thickness of the ice coats are most conservative. The plane used in the calculation is the Air Mail Douglas Type M-4. (Courtesy of Pilot Thomas P. Nelson.)

(FIGURE 60.) Resistance.

increased and the attachment of clogs of ice to propeller blades roughens engine action and may reduce the pull. **The lifting power** of the wings may be diminished by the change in the shape of airfoil by the head of ice on the leading edge (on upper side usually). (Figure 60.) **The weight of the ship** may be increased to an amount in excess of the maximum loading. Much diversity of opinion has been found as to the relative weights of the first two actions; there is almost unanimity that the actual weight of the ice is the minor consideration in most flights because the extra load might easily be carried if other factors remained unchanged. All three ways combined have however a powerful influence upon flight and have been said to be sufficient to force a plane to settle after less than ten minutes of exposure to the ice forming conditions.

These conditions, until recently little studied and less understood, are present **whenever water particles** impinge upon the plane's surfaces in flight through air at temperatures below the freezing point (32° F or 0° C). These particles may be big enough to be raindrops falling through sub-freezing air; on the other hand they may be tiny particles of fog or cloud at temperatures as low as 21° below zero F. While they may be existing as water droplets in the free air, upon impinging against the leading edges of the plane's surfaces they change immediately to glaze (silver thaw of the British).

Vertical cross-sections of the atmosphere during the fall of freezing rain are generally on the following order. Near the surface in a wind from some northerly quarter the thermometer reads about 25° F. and the humidity is moderately high. Up to the cloud-sheet's base at about 2,000 ft. the **temperature falls** steadily to about 18°, the humidity correspondingly rises, and the wind veers into an east or southeast source. At the cloud base a rapid rise in temperature, a saturated condition of moisture and a drift of air from south are to be found, and within this cloud base temperatures may be considerably above

the freezing point. Such clouds are 2,000-4,000 ft., and within them a second temperature fall with increasing altitude sets in. As a result, it sometimes happens that in this rain-making factory rain is turned out in the lower reaches while snow is produced higher up which in falling through the warmer layers is melted to a liquid or perhaps colloid state.

The rain-factory marks the turbulent and intermixing air which is sandwiched between a heavy cold stream below and a light warm mass above. This condition persists as long as each current can be maintained and vanishes when either is occluded. It is in falling through this lower reach of sub-freezing atmosphere that the raindrops attain to temperatures similarly low, and when they break against any object are promptly congealed. Sometimes they are congealed in mid-air and the result is those frozen pellets of ice which are termed sleet. When an airplane flies through air containing sub-cooled raindrops, its surfaces in smashing the surface tension of these drops provides the trigger action to set off **immediate crystallization** upon the plane, with the result that a coating of ice immediately builds into the wind from all leading edges on the plane.

In addition to the danger of taking ice when falling rain is found freezing on the ground surfaces there is some danger when the rainfall is occurring with surface temperatures between 32° F. and 40° F. if the plane is taken up over altitudes of 2,000 to 4,000 ft. above ground. Ice can then be taken as a result of the temperature lapse with altitude which is about three degrees F. for each thousand feet under such conditions.

The structure of the air which has just been described as existent during the fall of freezing-rain (sometimes called glaze) is slightly modified in the condition technically called a sleet-storm. **Sleet is a precipitation of ice-pellets,** which are really congealed raindrops frozen completely as they have fallen through the cold substrata of the atmosphere. It is likely that sleet results when a generally colder state of affairs exists aloft than is found when sub-cooled rain falls; quite possibly it is safe to assert that at the upper levels, sleet originally may have been snow-crystals, then melted to a mixture of slush and water in active condensation, and while in this state frozen into pellets of sleet, all this series of change occurring as the condensed particles fell through the air.

Sleet if completely frozen is not capable of sticking to the planes. Flights through sleet unattended by rain can be safely made, although the pellets may attack fabric or wood surfaces. The caution which should be emphasized as necessary in the sleet-storm is to the effect that the pilot must beware of taking his plane into a zone where rain mixed with the sleet will introduce the ice-hazard. Or he may be compelled by hills to climb to an altitude which will force him into the cloud-ceiling. Here freezing clouds will make ice barnacles at a dangerous rate. This will be described later.

A flight through a sleet-storm was made by pilots in a Liberty engined Fokker biplane from Hadley Airport to Bolling Field, Washington, Dec. 4, 1927. The factors involved in this instance were weighed carefully and the weather conditions likely to be met were discussed with the writer with a view to getting the plane through if this could be considered at all feasible and safe. At Hadley sleet (without any trace of rain) was falling steadily from a 3,000 ft. ceiling, visibility five miles, surface wind N.E.—26 m.p.h. becoming 40 to 50 m.p.h. at 3,000 ft. and temperature 24° F. At Washington the conditions were almost precisely the same, the ceiling being slightly lower and the temperature 26° F.

The flight seemed feasible because the strong tailwind would send them southwestward at a fast rate sufficient to make them cross over a landing field every ten minutes, and they were cautioned not to attempt to reach up too close to the ceiling and to be prepared to descend in case the sleet should turn to rain, an eventuality that is difficult to exactly foretell. A course inland was safer than over the water. **The storm center was off** the Carolinas' coasts moving northeastward, and if the flight was much delayed would have allowed it to move so near Washington that the warmer and moister regions of the storm would close down on the course. This rare instance of all elements being favorable for flight was a notable success and the flight lasted 80 minutes only, at which time they descended to the surprise of Bolling Field, and reported that once near Baltimore ice began to form on the windshields, but was a local and transient condition soon left behind. This flight emphasizes the need for full, completely accurate and well-studied meteorological advice before attempting flight. Its rarity is the exception to the rule that sleet and ice are too dangerous for flights of any length of time or distance.

Besides occurring as falling drops of water (rain) **the subcooled moisture** may remain in suspension aloft as cloud or fog. Because of its stealthy onset, its occurrence throughout a big range of sub-freezing temperatures, and the restrictions which such a cloud ceiling may set upon altitude to which a plane may ascend, this type of ice-barnacle challenges designers, pilots and weathermen alike. No dependable device to rid the plane of ice has been found, nor one to prevent its attachment; no designer has a creditable record for making planes invulnerable to ice, and we still lack an entirely proven explanation of the physical processes involved.

About these processes several features are so unmistakably prominent that when taken up in connection with the theories which best fit the facts they may be said to represent the truths as we know them in the present imperfect state of our knowledge. It has been our privilege to hear numerous details recounted by the pilots who have flown in and out of this airport during the past two winters; we have to bear in mind however that the pilots have such demands upon their attention at the onset of this ice that they may well be excused if their reports do not contain all that we would like to know. To continue investigations of the nature of the processes involved in this most harassing danger of the free-air, it is hoped that the Weather Bureau may be able to have recording instruments synchronized to record on a graph the temperature, humidity, and altimeter readings of instruments mounted on the wings of the planes.

One of the proven facts is that **clouds composed of ice crystals** or snow yield no ice to the planes. These clouds are however comparatively rare at ordinary altitudes and the best example of such a cloud is the mare's tail cirrus fibers which float at great altitudes. Another kind of cirrus cloud covers the sky with a greyish pall and causes rings (halos) around sun and moon. But these snowdust clouds are not frequently found at flying altitudes. All other clouds seem capable of making ice when their temperatures are below the freezing point of water, and as a result of optical phenomena often observed, the meteorologist understands them to be composed of minute spheres of water. **These wet clouds** run the whole gamut from the thick, high masses of water vapor just on the verge of rain to the thin shapeless masses of haze and vapor which have hardly become cloud, and throughout this range they are potential ice-makers. In fog (cloud on the ground) temperatures as low as 21° below zero F. have been trustworthily observed and the vapor particles found to be tiny water droplets.

While the mysteries of the subcooled but unfrozen water droplets await final detection, some fairly acceptable theories may be put forward. **In changing from the vapor** to the solid state many kinds of matter take an intermediate liquid form. In those substances which crystallize, such as water, it seems that this crystal making force is suspended awaiting the trigger-like set-off of some obscure catalysis, which once introduced permits rapid extension of the crystal action. Subcooled water globules may perhaps be imprisoned within a shell surface tension or electrical charges which must be broken before the perfect equilibrium of the forces is shattered and ice results. In the free air, perhaps this shattering is quite uncommon, except in the turbulence of storms. Snow has been explained as developing from these minute water spheres by a process which assumes that crystallization occurs on certain spheres, resulting in minute hexagonal plates which in contact with other water droplets attach these to themselves and grow into the beautiful forms which we find in falling snowflakes. Microscopic studies of snowflake details show evidence of imprisoned water within the structure of them and such flakes may have grown very fast.

And while this water vapor cooled far below the freezing point and saturating the space where we detect clouds may resist crystal action when unmolested, once smashed by the impact of the various parts of an airplane, ice forms forthwith with an appalling alacrity. As the droplets impinge on the leading edges they build forward into the wind "**heads**" **of ice** which may so alter the shape and cross section of members of the plane's structure as to be responsible for the flight-curtailing results so often felt. It has been deemed safe to assume that the temperature of the plane's parts can be but little different from the air in which the vapor exists. Once begun the process seems to proceed with added rapidity.

To take ice rapidly it is assumed that the air must be saturated with water where the plane is flying. The temperature of this air must be below 32° F., and perhaps down as low as 10° or 15° F. In the vicinity of zero and thence lower the amount of vapor which can remain in the air when saturated becomes so small that even under these conditions of saturation the amount of ice collected in a short time becomes so small as to constitute little danger, because before they overwhelm him the pilot can escape to more favorable locations. As a rule the lower the temperature the more frostlike and white is the deposit of ice; near 32° F., occasions have been reported of a nearly transparent coating being taken, assuming when becoming heavy a ripple-like surface in appearance much like the wind whipped sand-ripples frequently observed on beaches. Such roughened or wavy coatings aggravate the tendency already developing for the ice to increase head-resistance and decrease the suction side of the lift of the wings; if not promptly evaded or cleared it is likely to prove disastrous to any type of plane now in regular flight-work.

Once a plane has become iced-up, **two alternatives for clearing away the accumulations** of glazing may be available as a result of properties of the air itself at some certain level. One is to climb sufficiently to come clear above the clouds. Here the ice will disappear by rapid evaporation to the comparatively dry air clearly shown by the absence of cloud; if very dry then the ice literally vanishes as if melted away, although the action is entirely one of evaporation directly from the ice into vapor (known as sublimation). This method of shedding ice is certain and puts the airman where he will take no more, but it is not usually as practicable as desirable. For one reason the plane which is feeling the effects of ice must climb fast through the clouds at a time when it is becoming increasingly difficult to maintain even a constant altitude; for another the feat may almost be accomplished but fails and then the craft stands in danger of getting a dangerous icing on the way down through the clouds. Breaks in the cloud sheets sometimes can be taken advantage of.

The other alternative for shedding the ice also has drawbacks. It consists of "hedge-hopping" at the lowest levels possible, thereby keeping out of the clouds and also at the same time making the most of any temperature increase which usually takes place with decreased altitude. The action here is usually both that of evaporation and melting. It is feasible when the cloud does not rest on the ground as fog and when the terrain is fairly level. In crossing ridges, an airman must know his route well to keep from "piling up."

In the daily Weather Chart for 8 A. M., Dec. 20, 1927, weather conditions which were attended by icing up on the Cleveland-New York airway are shown. (Figure 61.) The case is typical, and the attention of pilots may well be drawn to the fact that upon casual examination this may look like a fair-weather map with west and northwest winds, and the weather reports from many city stations show cloudy or partly cloudy skies which usually mean satisfactory flying. These clouds may completely enshroud the higher ridges. They consist of masses of moisture released from the Great Lakes whose temperatures during the main part of winter are higher than those of surrounding regions and of the air which drifts down from interior Canada across them. Turbulence within this wind induced by both its rapid motion and the rising ground of in-

AIRWAYS WEATHER REPORT.

December 20, 1927.

Altitude	Place	Hour	Weather	Ceiling	Visibility	Wind	Temp. °F.
130	Hadley	Noon	O'cast	3500	15	WNW-18	34
		9 p.	Broken Clouds	6000	16	NW-19	34
1940	Park Place, Pa.	9 p.	Light O'cast	2500	20	NW-24	21
800	Tamaqua, Pa.	11 a.	O'cast	1800	25	W-15	34
1130	Numidia, Pa.	9 p.	O'cast	2000	25	NW-15	26
2200	Winkelbleck Mt., Pa.	9 p.	O'cast	800	15	NW-22	30
1000	Bellefonte, Pa.	11 a.	O'cast Freez. Mist	1000	20	W-10	34
		9 p.	O'cast	1700	7	NW-18	34
1810	Snowshoe, Pa.	9 p.	O'cast-Lt. Snow	800	8	NW-30	26
1960	Rockton, Pa.	9 p.	Foggy Rain & Sleet	0	0	NW-15	25
1410	Du Bois, Pa.	11 a.	O'cast Rain & Snow	800	2	W-16	28
1460	Clarion, Pa.	8 p.	O'cast Snowing	300	3	W-12	30
780	Cleveland, O.	Noon	O'cast Snowing	800	¾	NW-20	30
		9 p.	O'cast	900	14	NW-15	32

(FIGURE 61.) Weather Conditions.

land Ohio and Pennsylvania soon stirs this moisture up to be chilled into clouds whose baleful and insidious ice-tentacles are ready to grasp our finest air craft.

The problem of ice-barnacle action will have to be solved before regular transport lines in many regions can be said to be even partly independent of the weather. The problem challenges the best engineers. **Thus far, the application of various soluble, saponaceous, and oily substances** to the wings has helped for a brief time to prevent ice there but the action is short lived and too incomplete for safety. To eliminate struts, wires and all possible exposed surfaces, is to attack the problem in another way. Suggestions have also been advanced that metal planes can be heated to prevent ice, and this suggestion must be given careful consideration; it has the merit of being continuous in action and positive in results. It must however be developed on a scale commensurate with the great lavish expenditure of energy we have to deal with when we search into the secrets of free air. In the meantime it will be of value for the pilot to think of this ice action in terms which in imperfect completeness have been already discussed, with the hope that any further data of interest be brought to the attention of those best suited to interpret and study them.

CHAPTER XIII

The Atmosphere is an envelope of gas surrounding the Earth. It has neither taste, visibility or odor. Air is gas and has all the properties of gas:

(a) It cools with expansion.
(b) Heats with compression.
(c) It will occupy all of the space open to it.

The four chief constituents of pure dry air are:

Nitrogen, Oxygen, Argon,
Carbon Dioxide (Carbonic Acid Gas).

The winds keep the air in a state of perpetual motion, and as a result of this mixing process, the composition of the air is nearly constant and uniform all over the Earth.

With change of altitude this is not the case. The heavier gases remain close to the Earth and the lighter components at high altitudes predominate. Therefore, to fly at a height of 20,000 feet or more, without oxygen tank equipment, is dangerous and in some cases fatal.

With a constant temperature, a definite volume of air will vary inversely as the pressure; i. e., the greater the pressure the smaller the volume.

The amount of water vapor in the air never exceeds more than 4% and this percentage is changing constantly with varying weather conditions.

The atmosphere is divided into two separate and distinct regions:

1. The upper region known as the Stratosphere.
2. The lower region known as the Troposphere.

The line dividing these two regions is called the Tropopause.

The Stratosphere, an area of calm weather, is of no practical importance to the pilot at the present time.

The Troposphere, the storm area, reaches to a height of approximately 40/50,000 feet in the temperate zones and from 45/56,000 in the tropics.

Atmosphere Dust is a very important physical feature.

1. It is one of the principal causes of haze.
2. It acts as a nucleus for fog particles and rain-drops.
3. The colors in the sky at sunrise and sunset owe their presence to this dust.
4. Twilight is due to the reflection of sunlight from the dust after the sun has disappeared below the horizon.

Convection is the transference of heat from one point to another by circulation. The warm air rises and due to the decrease in pressure with altitude, it expands and grows cooler at the rate of 16° F. for each 300 ft.

(FIGURE 62.) Warm Air Rising.

This decrease in temperature, however, is only in air free from water vapor. Under normal conditions this would be 1° F. for each 300 ft.

Convection in the atmosphere takes place due to the irregular heating of the bottom, at one place more than another.

There is, therefore, a permanent convectional circular movement between:

1. The Equator and the Pole. This establishes the general wind system of the globe.
2. Continents and nearby oceans—The origin of Monsoons.
3. Between land and sea—Land and sea breezes.
4. Localities and surrounding places—Local winds, storms, thunderstorms, cloud formations.

Cumulus Clouds are an excellent example of Convection.

Masses of white ball shaped clouds with rounded summits, flat at the base, they are nothing more or less than the heads of rising columns of warm air—"A pocket of warm moist air forced to rise due to convection." (Figure 62.)

> "The moisture in the air condenses in the higher and cooler Atmosphere and the cloud is formed."

Conduction is the transference of heat from one body to another, or part of one body to another part. The elements met with in Meteorology, unlike metals, are poor conductors.

During the day, due to the sun, the ground may become very warm, but at night it cools off rapidly through radiation.

The heat of the ground has little effect on the air. A poor conductor, air may be in contact with the ground many degrees hotter than itself for a considerable period of time and yet, only the lower few feet would be noticeably heated.

Insolation may be expressed as the radiant energy which, in the form of ether waves, reaches the Earth and warms it.

Condensation is the passage of the moisture of the atmosphere from the invisible gaseous form, water vapor, into some visible, solid or liquid form: fog, clouds, rain, snow, hail, frost, dew.

When the atmospheric pressure at any place is lower than in the surrounding areas, the air at that place rises and, if the humidity of the rising air is high enough, it will carry a quantity of water vapor with it. As the column of air rises, it expands still further owing to the rarefied state of the upper regions, the expansion being accompanied by loss of heat, which, together with the prevailing temperature, causes the water vapor to be condensed.

The result is seen in the appearance of any of the seven forms of condensation already described.

Rain generally falls from numbers of Stratus Clouds.

At any moment the air contains a certain quantity of water vapor; the proportion varies from place to place and from time to time. When the air contains as much water as it can possibly hold, it is said to be saturated. The actual amount of water vapor in the air is called the "**absolute humidity**" of that air.

The important meteorological matter, however, is "**Relative Humidity,**" which may be defined as a ration of the actual amount of water vapor present in the air to the amount which the same volume of air would hold if it were saturated. It is usually expressed as a percentage. When the percentage is 100, the air is said to be at "**Dew Point.**" If air only partly saturated with water vapor be cooled, the temperature will be reached sooner or later at which the water vapor actually will be sufficient to saturate that air. Any cooling beyond that point (the Dew Point) will cause some of the water vapor to condense in the form of liquid water.

Humidity is the state of the atmosphere as regards moisture.

Water vapor and humidity both refer to water in the atmosphere and are practically the same. Water is always present in the atmosphere in an invisible gaseous form.

Water vapor is derived from the following sources by the process of evaporation: i. e., changing water from the solid or liquid state to the invisible gaseous state.

1. The water surfaces of the Earth.
2. The surface of the ground.
3. The vegetation of the Earth.
4. In a minor degree, the lungs of animals.

Water vapor is lighter than air, and this being so, a moisture laden atmosphere is lighter than a dry atmosphere, due to the replacement of a proportion of Dry air by water vapor.

Whilst the change from a solid or liquid state to a gaseous is called evaporation, the opposite to that is called condensation; and condensation is the transforming of the invisible gaseous form to some other form such as rain, dew, snow, hail, frost, fog, clouds.

Evaporation is considerably faster when conditions of high temperature and high winds prevail than when the atmosphere is full of moisture.

N. B.: As the temperature increases, the capacity of the air for holding water vapor increases proportionately. As the temperature decreases, the reverse happens and the dew point is reached.

Air Pressure. The atmospheric air exerts a pressure in all directions, and the amount of this pressure varies according to the density of the air. The air at sea level, weighted down by the air above it, exerts a pressure of nearly 15 lbs. per square inch of surface against which it presses.

The air pressure decreases with increase of altitude and at an altitude of a few miles it becomes very small.

Pressure is the most important of the meteorological elements because all the other elements—wind, humidity, and the rest—seem to depend upon it, or, rather, upon its changes. In any room there are some crevices and through these crevices the air will flow in the endeavor to settle down in equilibrium, and such equilibrium is attained very rapidly. Therefore, the atmosphere is regarded as having the same pressure at the same levels so long as the air is not moving; and the movement of the air is regarded as a component in the equalizing process.

The pressure of the atmosphere is measured by means of barometers. There are two kinds of barometers. First, those in which the pressure is balanced by the weight of a column of liquid, and second, those in which the movements of the flexible lid of a box which is nearly exhausted of air are recorded.

Temperature. In addition to the difference in temperature over the surface of the earth, the local daily and seasonal variations due to wind and the unequal heating and cooling of the earth, temperature decreases regularly with increased altitude; occasionally local inversions of the rule are expressed, but normally there is a fall in temperature of 1° Fahrenheit (approximately) for every 300 feet. The chief factors determining temperature are sunshine and cloud, distribution of water and land, height and wind. The effect of the latter is influenced by the sea and land over which the wind passes.

It is also important to note that a decrease in temperature is caused by expansion, i. e., reduced pressure, so that a decrease in atmospheric pressure will cause a cooling of the air. Lines joining places at which the temperature is identical at the same time are called Isotherms.

The Inversion of Temperature. After a height of approximately 6 miles has been reached, the temperature does not drop with elevation, but has a tendency to increase slightly. This layer of constant temperature is known as the Isothermal Layer or Warm Stratum. As a result of tests made with observation balloons, in this country, some interesting data is available.

> The temperature at 47,500 feet was — 90° F., whereas, at the maximum altitude reached—54,000 ft., the temperature had risen to — 72° F. Another test showed — 80° F. at 39,500 and — 69° F. at 42,200 feet.

Inversion of temperature is frequently met with close to the ground; in hilly or mountainous country the temperature at the higher levels being warmer than in the valleys or low lying areas.

Inversion of Temperature may be defined as the reversal of the normal Vertical Gradient of Temperature in the atmosphere; an increase of temperature with increase of altitude.

WIND.

Wind is the motion of the air and is due to the unequal warming of different parts of the earth by the sun. It is stronger by day than by night, increasing in velocity as the sun rises and dropping again towards evening as the sun sets.

It is a well-known fact that definite belts of high and low pressure exist at various altitudes, causing more or less constant prevailing winds. These belts are inclined to move bodily North or South through a few degrees at different times of the year, causing climatic changes. They are also broken in places, and the winds are not always exactly what one would expect owing to the large masses of land and water, such as continents and oceans, etc.

At the Equator air is at extreme heat and by convection rises, resulting in a belt of low pressure and of calms and rains. Since pressure always tends to equalize itself as water tends to "find its own level," so air flows from two belts of high pressure situated at about Lats. 30° N. and S. towards the Equator, and also towards two further belts of low pressure situated near the Poles. If the Earth were stationary these winds would blow due N. and S., but owing to the **rotation of the earth** they are **deflected** to the right in the Northern Hemisphere and the left in the Southern Hemisphere.

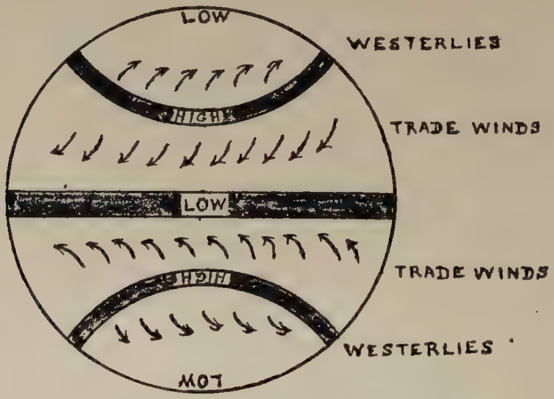
We have therefore the prevailing N.E. and S.E. Trade Winds near the Equator, and in the Temperate Zones the South Westerly Winds of the Northern Hemisphere and the North Westerly Winds of the Southern Hemisphere. These are most important factors in the resulting climate and weather experienced in any country, but no definite rule can be laid down.

They are subject to inversion and variations, and in the final determination of climate are interdependent with:—

1. Distribution of land and sea.
2. Temperature and temperature changes resulting from local pressure, ocean currents, and type of country.

Inversion of the Wind. At the surface of the Earth, during the day, the wind is much stronger than at night, and is at its highest velocity at mid-day; whereas, at a distance above the Earth the reverse is the case.

Planetary Winds are those Winds which blow on any Planet rotating from West to East on its Axis and that are heated at the Equator.



(FIGURE 63.) Planetary Winds.

Trade Winds. The great streams of air constituting the Trade Winds average nearly two miles in depth. The N.E. Trade over the Atlantic has a mean velocity for the whole area at the surface of about 10.5 miles per hour, varying from a mean of about 7.5 MPH in October to a mean of about 13.5 MPH in April. The S.E. Trade over the Atlantic has a higher mean velocity of about 14 MPH for the whole year, varying from a mean of about 13 MPH in January to a mean of about 15 MPH in April, June and August. (Figure 63.)

Westerly Winds Northern Hemisphere. The Westerly Winds blowing from the outer margin of the N.E. Trade belt are by no means so steady as the West winds of the Southern Hemisphere. They are frequently interrupted by storms, and the Northern Temperate Zone on land is characterized by such a succession of shifting winds that the prevailing direction of wind movement from the S.W. or West is not very apparent unless carefully checked by records. (Figure 63.)

Periodic Winds, Local. They are periodic winds which do not depend on the general or secondary circulation of the atmosphere. They are the Land and Sea breezes, Mountain and Valley Winds, Monsoons and Chinook Winds.

Gradient Wind. Gradient Wind is a wind at about 2/3,000 feet above ground level, where the direction is practically parallel to the Isobars and the velocity is not influenced by ground objects. It follows, therefore, that if the surface friction effects, always local and uncertain, are to be avoided, as accuracy in Air Navigation requires that they should, **flight at a lower height** than **2,500 feet** should be avoided. The effect is much less over the sea. Also, change in wind is not so great above the sea as over land.

The velocity of the wind increases with altitude as the following table will show:

Take surface velocity as 1.0.

Feet	Velocity
0.	1.0.
500.	1.3.
1,000.	1.5.
3,000.	1.75.
10,000.	2.15.

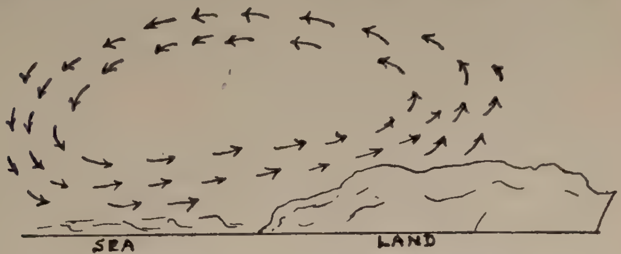
The rotation of the earth gives the air a spiral motion which is greater near the ground than at higher levels and as a result of this the wind veers as the altitude increases.

Height in Feet	Veering in Degrees
0.	0°
1,000.	10°
2,000.	15°
3,000.	18°
4,000.	20°
10,000.	25°

Strength of the Wind. The strength of the wind depends upon the pressure gradient. If Isobars are close together, the pressure gradient is steep and the winds are strong; if Isobars lie far apart, the winds are low. The Beaufort Wind Scale is used chiefly to classify winds of different forces.

Mountain and Valley Winds. Mountain and valley winds occur in mountainous regions in relatively quiet conditions of the air. There is then, especially in clear weather, an upward motion from the valleys during the day, and a downward motion towards the valleys at night. These winds have some analogy to the Land and Sea breezes.

In the night the cold denser air descends from the mountain tops, which cools very rapidly by radiation, toward the valleys below. These downward currents commence first in the narrow valleys on the mountain side, in which the air is heated during the day; but the descent soon becomes general, and the air flows down to wider valleys below. In the morning the air over lower levels of the ground becomes heated, and the surfaces of equal air pressure over those levels at some little distance away from the mountain are elevated, but directly on the mountain they are not, because there is no air below to expand upward; so that the air flows down these North horizontal surfaces towards the upper parts of the mountain, which it strikes at such an angle as to deflect it upward along the mountain side. In addition to this motion, there is an upward motion along the mountain side, due to the action of the sun's rays in the warming of the ground along the slope and the air immediately above it; so that the upward motion of the air along the surface of the ground is the result of these two motions combined. The accumulation of this air at the top of the mountain is prevented by horizontal currents which exist there.



(FIGURE 64.) Land and Sea Breezes.

Land and Sea Breezes. The land and sea breezes which are characteristic of the summer climate of nearly all sea coasts are analogous to mountain winds. The land becomes heated by day, a low pressure is produced, and a breeze blows in from seaward which continues until the evening. During the night the land loses its heat more rapidly than the water; the daytime conditions are, therefore, reversed, and a land breeze springs up which lasts until morning. (Figure 64.)

Squalls. A squall is a blast of wind of higher velocity than has been expressed on the average, occurring suddenly and lasting for some minutes at least, and dying away as suddenly as it rose. A gust is also a sudden increase of wind, but it is of very short duration. The effects of squalls on an airplane are as follows:—

> "When flying against the wind, an increase of wind causes the airplane to rise, and a decrease of wind causes it to drop. Flying with the wind these effects are reversed. The maximum effect of a squall is felt during a turn."

Wind Gusts and Eddies. These cause a condition in the air, similar to a choppy sea, known as bumpy weather. Obstacles in the path of moving air at the surfaces cause them and are most noticeable in a strong wind. Strong cross-currents of air also make rough going, and are often indicated by criss-cross corrugated clouds. In mountainous districts the winds sweep down the mountain sides like aerial water-falls, and at the entrance to valleys and mountain gorges strong cross currents are set up, causing terrific bumps, in which the machine is often tossed about like a cork. Under such conditions, it is advisable to fly at sufficient height to avoid them. Low flying is exceedingly dangerous owing to the intense suction frequently experienced.

Line Squalls. A Line Squall is a Meteorological condition of considerable importance to aviators. The characteristics of a Line Squall are:

1. A sudden increase of wind followed later by a lull.
2. A change of wind direction—generally veering.
3. A sudden rise in pressure.
4. A long line of dark cloud with rain or hail.

Line squalls generally move from West to East. They may be two or three miles deep, but as much as 200 miles long. They are associated with a Trough, or Depression, the preliminary stages of a thunderstorm, or uniform isobars.

As a general rule it is impossible to fly round Line Squalls and the pilot is well advised to land until the storm has passed.

Bumps. Bumps erroneously called Air Pockets are due to atmospheric conditions, extremes of heat or cold and wind. They are encountered as high as 3,000 feet from the surface and as low as 50 feet. Over water, rivers, woods, valleys and narrow gulleys bumps are particularly prevalent. Also when flying close to and under clouds. Bumps are, therefore, often described as cloud bumps or ground bumps.

THE BEAUFORT SCALE.

Beaufort No.	Gen. Descrip. of Wind	Beaufort Scale	Velocity in M.P.H.
0.	Calm.	Smoke rises vertically.	Less than 1 mile.
1.	Light Air.	Wind direction shown by smoke drift but not by wind vanes.	1—3.
2.	Slight Breeze.	Wind felt on face, leaves rustle.	4—7.
3.	Gentle Breeze.	Leaves and small twigs in constant motion. Wind extends light flag.	8—12.
4.	Mod. Breeze.	Raises dust and loose paper. Small branches are moved.	13—18.
5.	Fresh Breeze.	Small trees in leaf begin to sway.	19—24.
6.	Strong Breeze.	Large branches in motion. Whistling in telegraph wires.	25—31.
7.	High Wind.	Whole trees in motion.	32—38.
8.	Gale.	Breaks twigs off trees. Generally impedes progress.	39—46.
9.	Strong Gale.	Slight structural damage occurs. Chimney pots removed.	47—54.
10.	Whole Gale.	Trees uprooted; Considerable structural damage.	55—63.
11.	Storm.	Very rarely experienced. Widespread damage.	64—75.
12.	Hurricane.		Above 75.

STORMS.

Thunderstorms. They can be grouped into three main classes:

1. Those due mainly to heated surface air in fine summer weather.
2. Those associated with powerful upper currents from the S.W., the surface wind being light, variable from S.E.
3. Those associated with low temperature in the upper air, chiefly in the South Westerly currents of depressions.

Thunderstorms of **type one** occur chiefly in the warmer regions of the earth during the warm seasons, and they are most violent, at that time of day, three to four o'clock in the afternoon, when the convectional up-currents, due to the great heating of the land, are likely to have reached their maximum. The cumulus clouds of an ordinary summer's morning are seen to develop upwards, their summits attaining heights up to 20,000 feet. If the summits of these largely developed clouds be watched, a curious change is seen to take place, the tops seeming to become flattened and covered with wisps or filaments of cirrus-looking cloud, termed "false Cirrus," which cover them as with fleecy mantles. Investigation has shown that the "false cirrus" is covered with snow. The lower the upper air temperatures are, the better are the conditions for development of these summer thunderstorms.

Thunderstorms of **type two** are due to a definite flow of cooler air over warm, instead of the direct heating of the land surface. Generally a warm surface Southerly or South Easterly current is overlain by a cooler South Westerly one. In such cases the curve representing the fall of temperature upward is very distorted and atmospheric instability is set up. Thunderstorms of this type are of common occurrence at night.

Thunderstorms of **type three** are associated with the very low upper air temperatures which are known to exist in the

Eastern part of a depression. If then the surface Southerly or South Easterly currents to the South East part of the depression be fairly warm, their displacement by the colder air from above may cause conditions suitable for thunderstorms. Generally thunderstorms of this type are not violent, and the conditions suitable for their development may occur either during the night or day.

Thunderstorms are a considerable source of danger to the pilot:

1. The vertical rising air in front of the thunderstorm has a lifting effect on the aircraft, but this being followed very closely by cool descending air; a tail wind develops, causing the aircraft to drop with imminent danger of crashing if flying low to the ground or attempting to land. Accidents have frequently occurred due to lack of knowledge of rapid winding veering in thunderstorms.
2. The extremely violent vertical movements within a storm, upward and downward. Under these conditions the plane is practically uncontrollable.
3. **Hail.** Approximately 20/50% of thunderstorms are accompanied by hail. In no time, the fabric on a machine would be cut and ripped to pieces followed by the inevitable crash.
4. **Lightning.** Cases are on record where machines have been set on fire and burned up through this cause.
5. Heavy blinding rains with poor visibility.

There are several courses the pilot may adopt to overcome these hazards:

1. The surest and safest is to turn tail and land at the most suitable spot until the storm passes. A delay is better than a crash, and cheaper.
2. Fly above the storm.
3. Fly around the storm.

Commencing 4/5,000 feet from the ground, the thunderclouds (Cumulus-Nimbus) vary in density but are often 15/20,000 feet in thickness.

The general direction of thunderstorms is from West to East. Extending only a few miles in width and to a lesser extent in length at the commencement, they increase rapidly in length to 150/200 miles and 40/50 miles in width. The average life of a thunderstorm is 6/8 hours and they travel at a velocity of 30/40 miles per hour.

A peculiarity of thunderstorms and of particular interest to the flyer is that thunderstorms rarely cross rivers.

They occur most frequently in the afternoon.

N. B.: **Under no consideration should a pilot attempt to fly up and through the storm clouds.**

A Tornado may be defined as a very violent, but short-lived, wind. It is a name applied to the small, but very violent whirlwinds of one or two hundred yards in diameter, which advance towards the East or N.E. at a speed of 20 to 40 miles per hour, the very strong winds destroying practically everything within the direct path. The activity of the tornado lasts for about half an hour. They are very frequent in the valley of the Mississippi and certain Southern states.

Heavy wooded regions and mountains are practically free from these.

The velocity of motion of a Tornado must not be confused with the Wind Velocity; this has never been measured. It is, however, well over 100 M.P.H. and may reach as high as 500 M.P.H.

Revolving Storms. Revolving storms are so named because the wind in these storms revolves round an area of low pressure situated at the center. In the Western Hemisphere they most frequently occur during the period covering July to November, and are commonly called Hurricanes or Tornadoes.

In these storms the wind always revolves the same way in the same part of the world, that is, against the movements of the hands of a watch in the Northern Hemisphere, and with the hands of a watch in the Southern Hemisphere.

The wind does not revolve in circles but has a spiral movement inwards towards the center. As a general rule revolving storms have also a progressive movement travelling from 5 to 30 miles an hour. This speed has no connection with the velocity of the wind however which reaches as much as 50 miles per hour. The smaller the storm the more dangerous it is and the greater its destructive qualities. The center of the storm is an area of dead calm with intermittent gusts of terrific intensity.

In Northern Latitudes they generally commence about 12° N. of the Equator, and travel in a W.N.W. and N.W. direction till about 25° N. where they recurve to the N.E.

In Southern Latitudes they generally commence about 10° South of the Equator and travel in W.S.W. and S.W. direction till about 25° S., where they recurve to the S. and S.E.

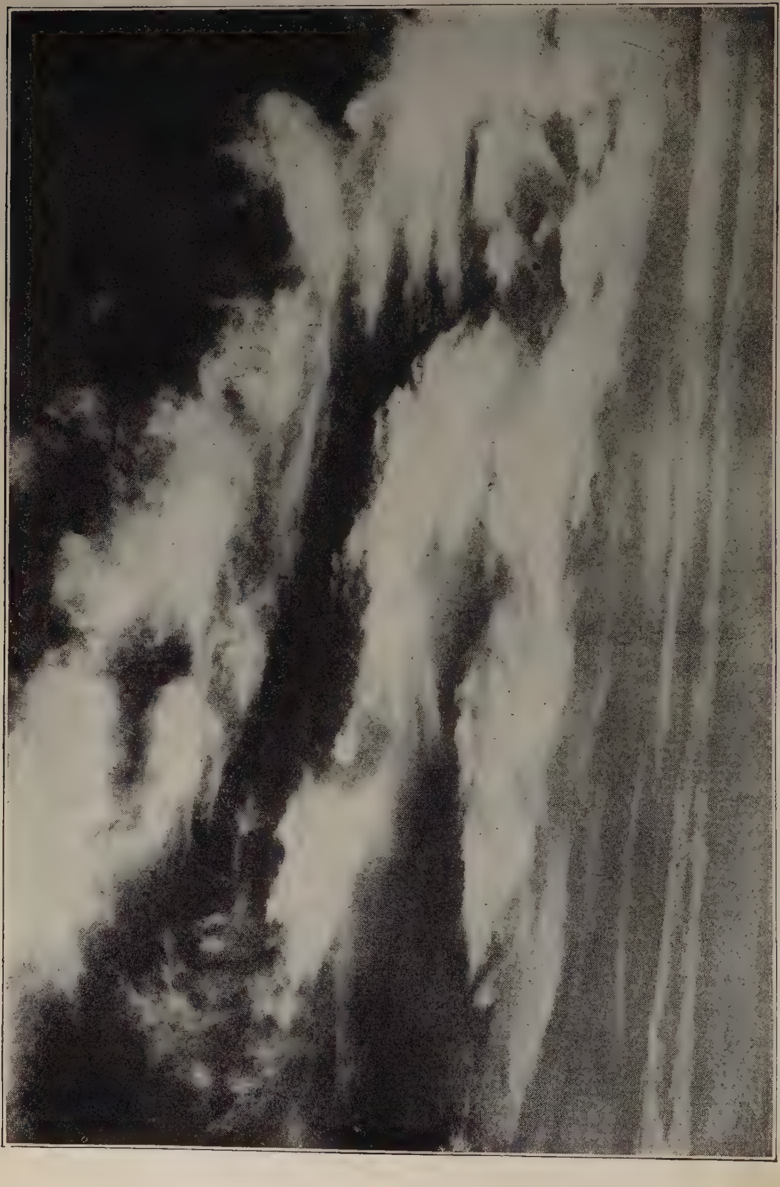
The track which the center of the storm takes is called the path of the storm, and the portion of the storm field on the right hand path is known as the right hand semi-circle, and that on the left as the left hand semi-circle of the storm. In the right hand semi-circle, if the observer be standing facing along the track the wind will always shift to the right, and in the left hand semi-circle to the left.

CLOUDS.

Cirrus. Detached clouds of delicate appearance, fibrous structure and feather like form, generally white in color.

Cirrus clouds take the most varied shapes, such as isolated tufts of hair, i. e., thin filaments of blue sky, branch filaments in feather form, straight or curved filaments ending in tufts, and others. Occasionally Cirrus Clouds are arranged in bands, which traverse part of the sky as arcs of great circles. (Figure 65.)

Cirro-stratus and Cirro-cumulus also are sometimes similarly arranged in long bands.



Through the courtesy of the U. S. Weather Bureau.

(FIGURE 65.) Cirrus Clouds.

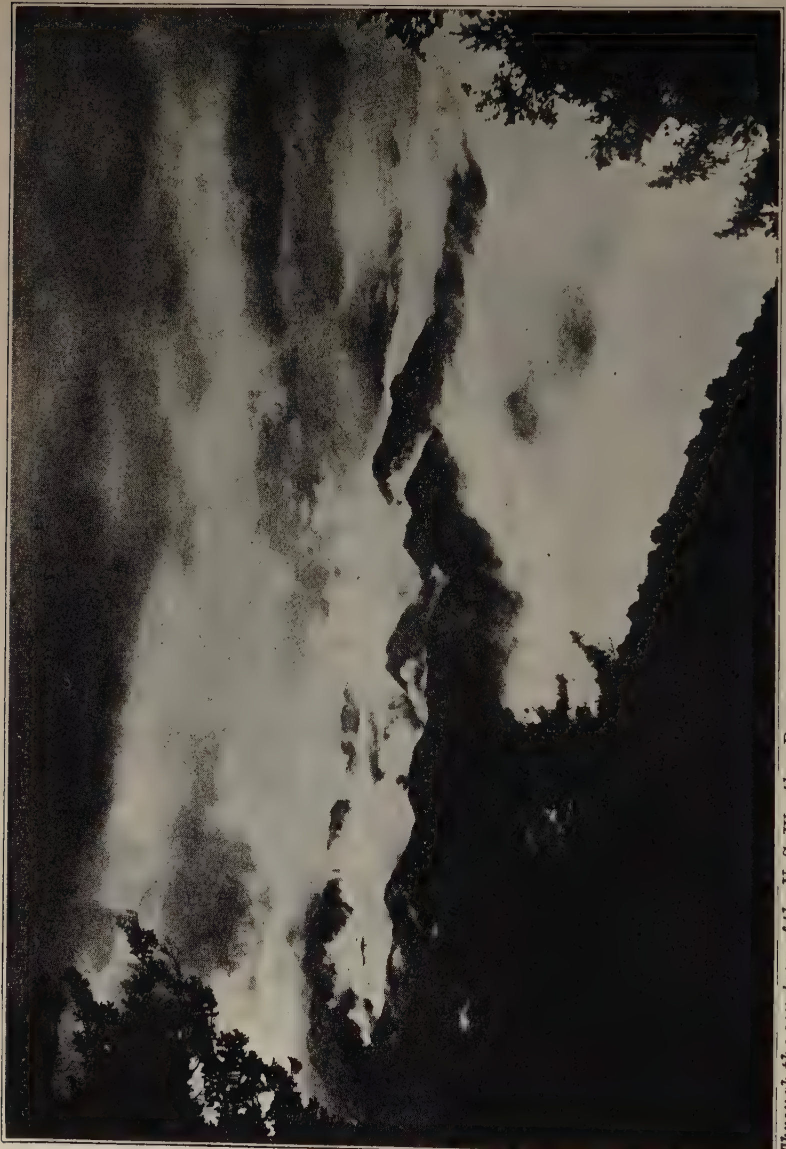
Cirrus-Stratus. A thin sheet of whitish cloud; sometimes covering the sky completely and merely giving it a milky appearance; it is then called cirro-nebula or cirrus haze; at other times presenting more or less distinctly a fibrous structure like a tangled web. This sheet often produces halos round the sun or moon.

Cirro-Cumulus. (Mackerel Sky.) Small rounded masses or white flakes without shadows, or showing very slight shadow; arranged in groups or often in lines.

Alto-Stratus. A dense sheet of a grey or bluish color, sometimes forming a compact mass of dull grey color and fibrous structure. At other times the sheet is thin like the denser forms of cirro-stratus, and through it the sun and the moon may be seen dimly gleaming as through ground glasses. Its normal altitude is about one-half of that of cirro-stratus.

Alto-Cumulus. Larger rounded masses, white or greyish, partially shaded, arranged in groups or lines, and often so crowded together in the middle region that the cloudlets join. The separate masses are generally larger and more compact (resembling strata-cumulus) in the middle region of the group, but the denseness of the layer varies and sometimes is so attenuated that individual masses assume the appearance of sheets of thin flakes of considerable extent with hardly any shading. At the margin of the group they form smaller cloudlets resembling those of cirro-cumulus. The cloudlets often group themselves in parallel lines, arranged in one or more directions.

Strato-Cumulus. Large lumpy masses or rolls of dull grey cloud, frequently covering the whole sky, especially in Winter. Generally strato-cumulus presents the appearance of a grey layer broken up into irregular masses and having on the margin smaller masses grouped in flocks like alto-cumulus. Sometimes this cloud-form has the characteristic appearance of



Through the courtesy of the U. S. Weather Bureau.

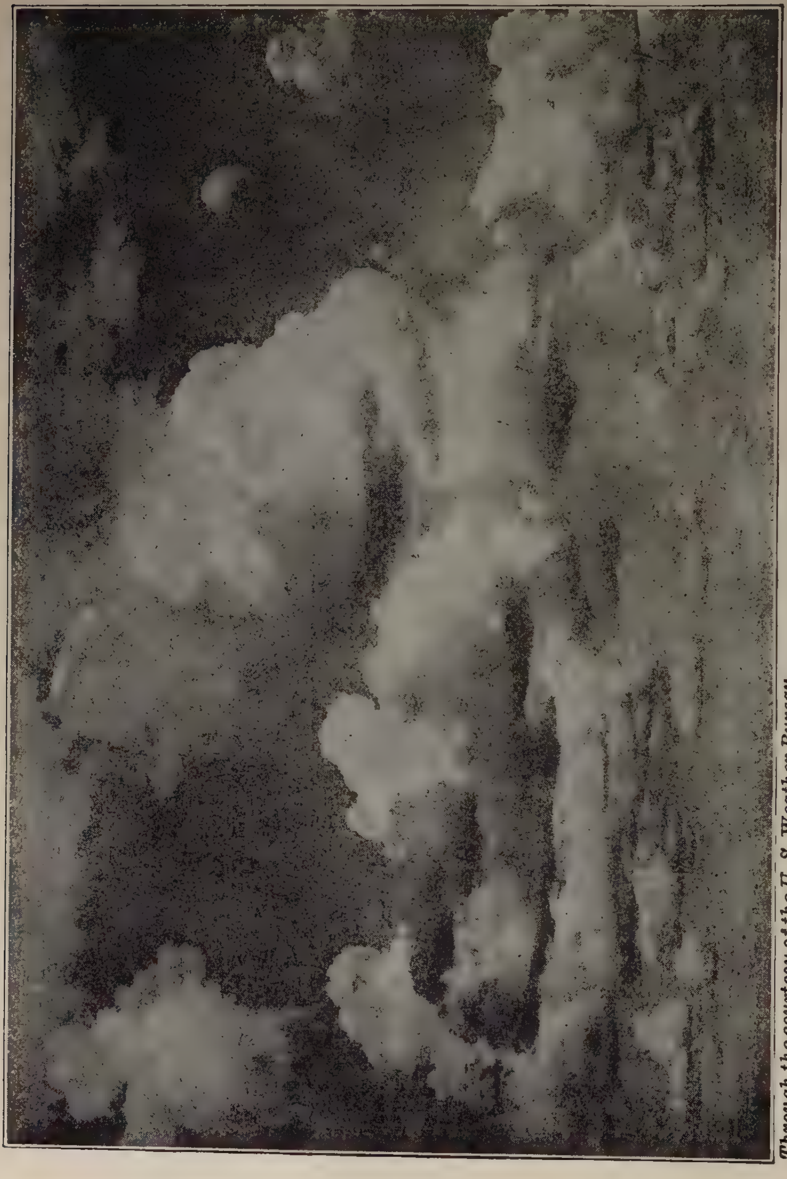
(Figure 66.) Nimbus.

great rolls of cloud arranged in parallel lines close together. The rolls themselves are dark and dense, but in the intervening spaces the cloud is much lighter and blue sky may sometimes be seen through them. Strato-cumulus may be distinguished from Nimbus by its lumpy or rolling appearance, and by the fact that it does not generally bring rain. (Figure 68.)

Nimbus. A dense layer of dark shapeless cloud with ragged edges from which steady rain or snow usually falls. If there are openings in the cloud an upper layer of cirro-stratus or alto-stratus may almost invariably be seen through them. If a layer of nimbus separates in strong wind into ragged clouds, or any small detached clouds are seen drifting underneath a large nimbus ("scud of sailors"), either may be specified as fracto-nimbus. (Figure 66.)

Cumulus. (Wool-pack or cauliflower cloud.) Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is generally horizontal. These clouds appear to be formed by ascensional movement of air in the daytime which is almost always observable. When the cloud and the sun are on opposite sides of the observer the surfaces facing the observer are more brilliant than the margins of the protuberances. When, on the contrary, it is on the same side of the observer as the sun it appears dark with bright edges. When the light falls sideways as is usually the case, cumulus clouds show deep shadows. True cumulus has well defined upper and lower margins; but one may sometimes see ragged clouds—like cumulus turn by strong wind—of which the detached portions are continually changing; to this form of cloud the name Fracto-Cumulus is given. (Figure 67.)

Cumulus-Nimbus. The Thunder-cloud and Shower-cloud. Great masses of cloud rising in the form of mountains or towers, generally having a veil or screen of fibrous texture (false cirrus) at the top and at its base. A cloud mass similar



Through the courtesy of the U. S. Weather Bureau.

(FIGURE 67.) Cumulus.

to nimbus. From the base local showers of rain or of snow, occasionally of hail or soft hail, usually fall. Sometimes the upper margins have the compact shape of cumulus, or form massive heads round which floats delicate false cirrus. At other times the margins themselves are arranged with filaments similar to cirrus clouds. This last form is particularly common with spring showers.

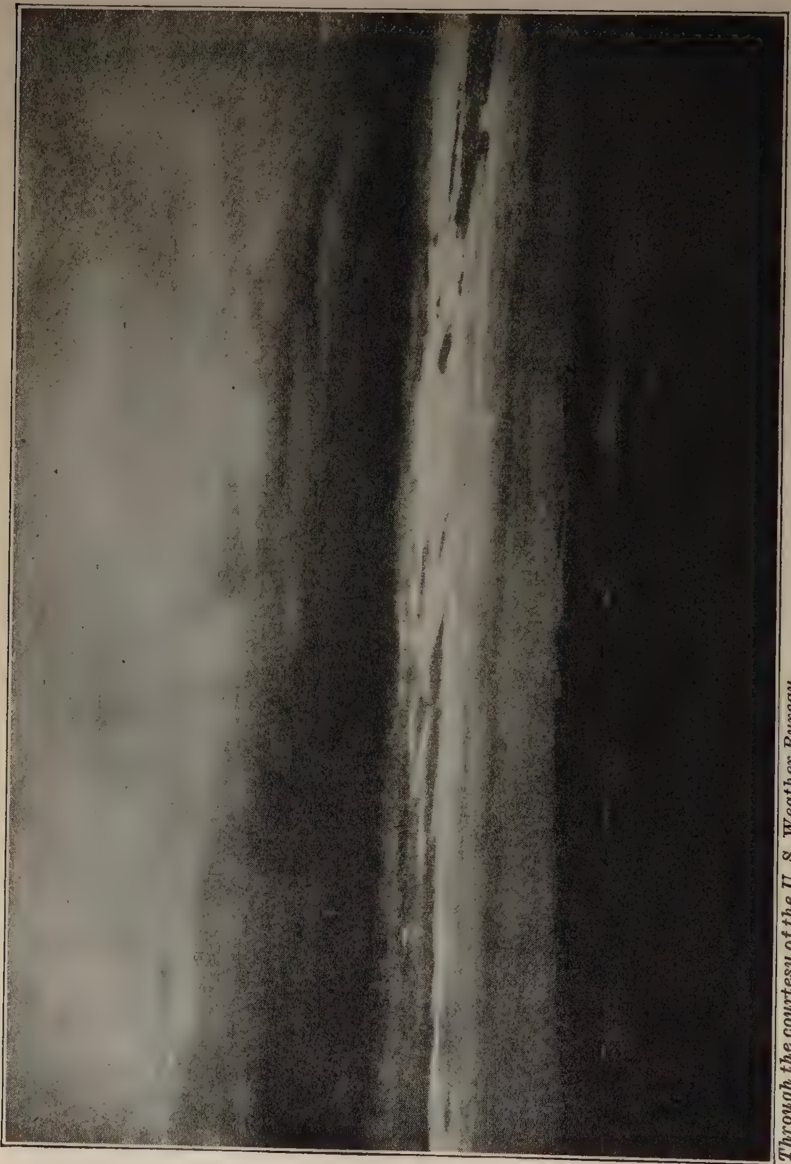
Stratus. A uniform layer of cloud like fog but not lying on the ground. The cloud layer of stratus is always very low. If it is divided into ragged masses in a wind or by mountain tops, it is called Fracto-stratus. The complete absence of detail of structure differentiates stratus from other aggregated forms of clouds. (Figure 68.)

In the daytime in summer all the lower clouds assume, as a rule, special forms more or less resembling cumulus.

The ten main types of clouds are sub-divided into:

Cumulus and Cumuli-nimbus are **Heap Clouds** and the remaining types cloud sheets. The Heap Clouds are characterized by considerable vertical structure but do not form horizontal layers. The height of Heap Clouds varies considerably. The mean height of their bases, from the ground, is approximately 4,500 feet, but they are often found much lower, and they extend in height from 6,000 feet up to even 25,000 feet.

Cloud Sheets are characterized more by horizontal extension than by considerable vertical structure. Sometimes the sheets have breaks in them. Quite often, indeed, the sheets are represented by just a few isolated clouds in a blue sky. The sheets vary considerably in thickness and, often, the sky shows several cloud sheets or layers existing at different levels at the same time. The height of cloud sheets is also very variable. Cirrus, cirro-stratus and alto-cumulus are generally above 25,000 feet; Alto-stratus and Alto-cumulus are generally between 10,000 and 25,000 feet; and Strato-cumulus, Nimbus and Stratus are generally below 7,000 feet.



Through the courtesy of the U. S. Weather Bureau.

(FIGURE 68.) Stratus Clouds.

Cirrus, Cirro-stratus, and Cirro-cumulus clouds are composed of **icy crystals.**

The study of cloud forms is exceedingly useful. It affords most invaluable information to the forecasters anxious to know what the weather is likely to be.

Weather forecasts are based upon observation of the Pressure, Temperature, Rainfall, Sunshine and direction and force of the wind. From this information, weather maps are compiled and issued daily by the Meteorological Office. It will be noticed the map is covered with a series of curving lines known as Isobars. (Figure 76.)

An Isobar is a line connecting all the points which have the same atmospheric pressure.

A Synoptic chart is a map of the area under consideration, showing the distribution of various meteorological elements such as wind, pressure, temperature and the like, over that region at a given time.

Movements of **High** and **Low Pressures** average:

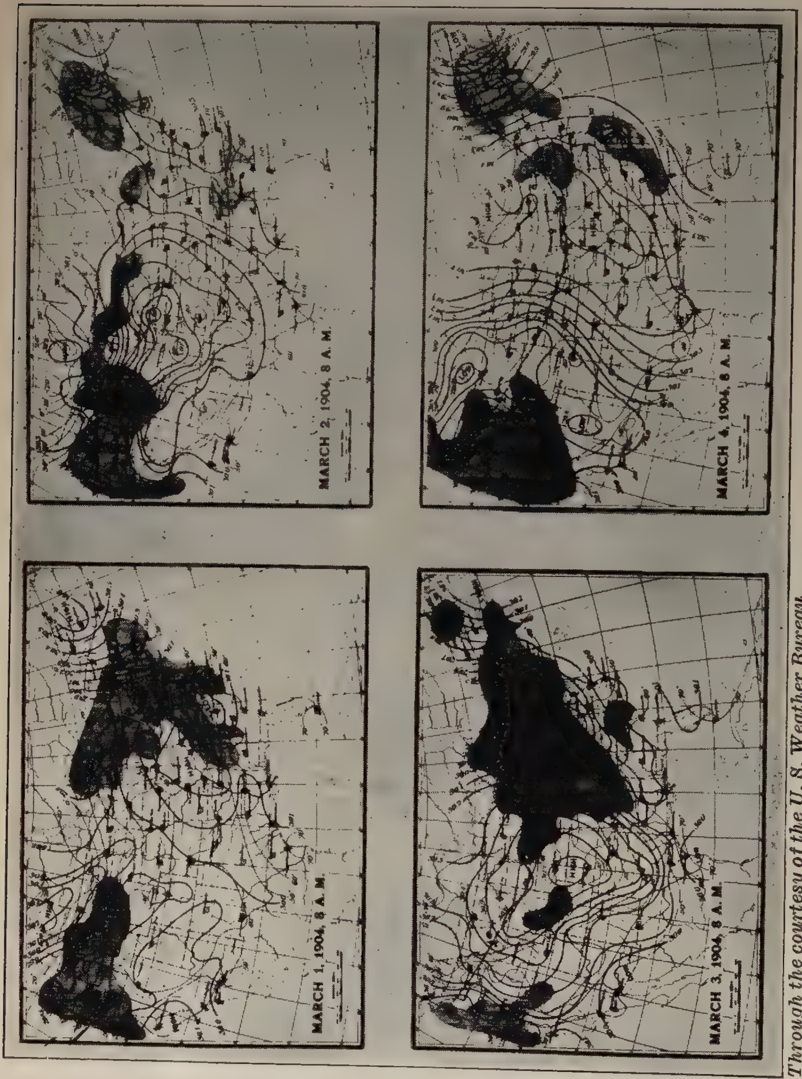
Low Pressures, 27/8 miles per hour.
High Pressures, 25 miles per hour.
Both High and Low move Eastward.

Direction. The general tendency of Lows when approaching the Atlantic Coast is to swing N.E. through New England to the St. Lawrence Valley and Newfoundland. (Figure 69.)

The proportion of poor flying conditions is greater therefore, in this area than any other part of the United States.

Highs also turn to the N.E., but proceed in the direction of Iceland or swing S.E. to Florida moving in the direction of Bermuda.

Flying conditions in this area are excellent throughout the greater part of the year.



Through the courtesy of the U. S. Weather Bureau.

(FIGURE 69.) Path of Storm.

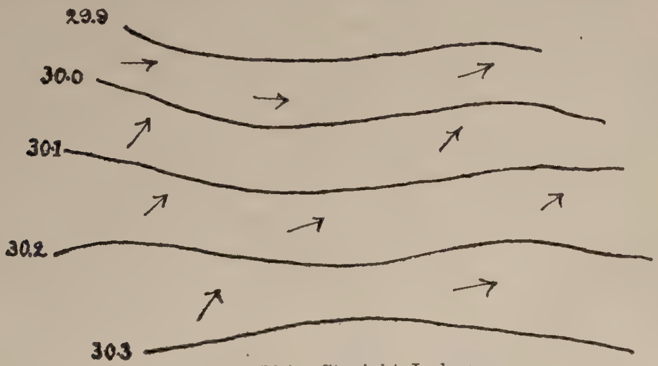
The wind direction is responsible for the great difference in temperature and moisture between the two sides of a Low. On the East side the wind blows from some Southerly quarter, bringing with it moist, warm-laden air and a rise in temperature. On the West side a Northerly wind prevails, resulting in cold dry weather. The N.E. part of a High is the coldest and the S.E. the warmest, due to the temperature of air by the winds.

Winds and Position. In a high pressure area, the winds have a spiral outflowing movement, turning clockwise in the Northern Hemisphere and counter-clockwise in the Southern. A region of High Pressure will always be found between two regions of Low Pressure. Two regions of Low Pressure cannot exist otherwise.

In a Low Pressure area the winds blow spirally inward toward the center, turning counter-clockwise in the Northern Hemisphere and clockwise in the Southern.

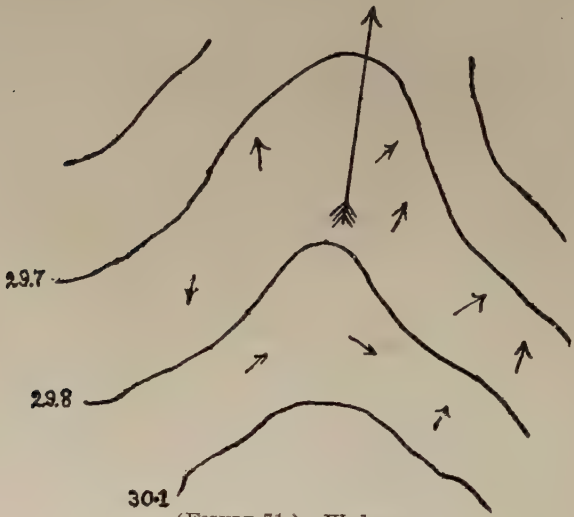
The movement of both High and Lows is faster in Winter than in Summer.

Straight Isobars. The regions of Straight Isobars separates centers of High and Low pressures. Usually the Isobars ex-



(FIGURE 70.) Straight Isobars.

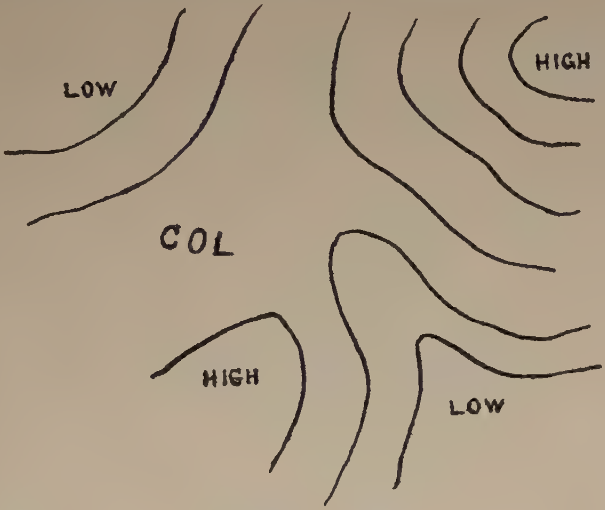
tend from W. to E. or from S.W. to N.E. Straight Isobars have no well-marked tendency towards any particular type weather; the region near the depression exhibits cyclonic tendencies, that near a high pressure, anti-cyclonic tendencies. Straight Isobars often extend over large areas. North to South Isobars sometimes occur. In spite of the apparent regularity of the Isobars and wind directions, sudden changes in wind direction and speed, with short duration variations of pressure and sudden showers occur, travelling across the Isobars. (Figure 70.)



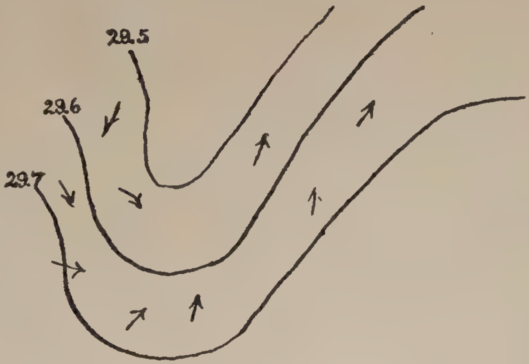
(FIGURE 71.) Wedge.

Wedge. The Wedge is a region of high pressure separating two lows. Generally, on the axis are light winds and fine weather. If the wedge passes from West to East, there is often showery weather on the front and finer weather at the rear. (Figure 71.)

Col. A Col is an area of almost uniform pressure between two highs and two lows. Its characteristics are—in winter, fogs, in summer, thunderstorms or rain. Occasionally a Col is accompanied by very good weather. (Figure 72.)



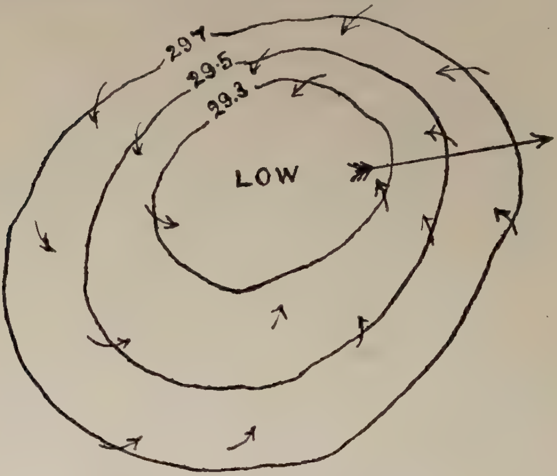
(FIGURE 72.) Col.



(FIGURE 73.) V-Shaped Depression.

V-shaped Depression. The trough of a V-shaped depression generally runs from about North to South; the depression generally moves from West to East approximately. The following sequences of weather are typical: (Figure 73.)

1.	The front approaches..	South winds, warm and moist. There is a narrow strip of cloud parallel to the axis and moving with depression. Rain.
2.	Trough passes	Sudden showers and fall in temperature. Line Squalls are a marked feature.
3.	Rear passes	Clear colder weather.

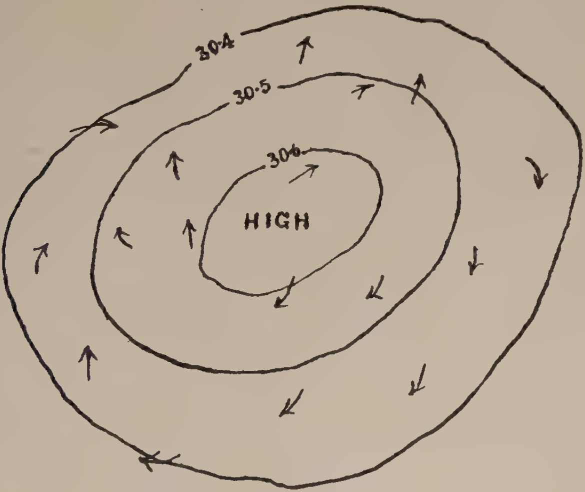


(FIGURE 74.) Low Pressure Area.

Secondary Depressions. The name "Secondary Depression" is of great extension. It is applied alike to a well-defined separate depression and to a mere bulge in an Isobar. A secondary depression generally moves in the same direction as the main depression. It sometimes happens that a secondary grows in size until it is bigger than the original main depression. Secondaries generally cause high winds and much rain. In summer shallow and slow-moving depressions often cause thunderstorms and rain.

Cyclone. Low Pressure Area. This is a part of the atmosphere where the temperature is lower than in the surrounding parts, and the Isobars around such an area are usually circular or oval. A wind blows around the depression in an anti-clockwise direction, and the nearer the Isobars are together the deeper is the depression and the stronger is the wind. At the front of the depressed area the sky is dull and overcast, with rain near the center and frequent squalls. At the rear, the clouds sheet is broken up into detached clouds which lessen gradually as the edge of the Cyclone is approached. The Barometer falls with the approach of the Cyclone and the temperature rises. (Figure 74.)

The Barometer rises again and the weather becomes cooler after the center of the area has passed.



(FIGURE 75.) High Pressure Area.

Anti-Cyclones. High Pressure Area. In summer, Anti-Cyclones generally bring fine, clear, calm weather during the day with much sunshine and high temperature, whilst at night the skies are clear but there is much ground mist or fog. In winter, however, there are two distinct types of anti-cyclones. (See Figure 75.)

1. Those in which the weather is fine during the day and very cold, with frost or fog, during the night.
2. Those in which the sky is persistently covered with low cloud shades, causing a dullness which is often referred to as ''anti-cyclonic gloom.''

In fact almost any kind of weather, except that of a violent nature is experienced.

It is a fallacy to regard anti-cyclones as, necessarily, areas of fine, balmy weather.

The Barometer. The study of the barometer is very useful and, with a good knowledge of this, weather conditions can be predicted pretty accurately.

Barometric Indication.	
Rapid Rise	Unsettled weather. Liability to sudden changes.
Gradual Rise	With a dry atmosphere fair weather. After a southerly wind improving tendency with wind from W. or N.W.
Rise after being low	First rising usually precedes heavy winds from the Northward. Continual rising indicates improving weather.
Steadiness	With dry atmosphere fine weather.
Rapid Fall	Stormy weather and rain. If accompanying a Westerly wind storm from Southward.
Considerable Fall	High wind. Rain or snow. North wind if thermometer is low. South if it is high.

Fall after being normal	With rising thermometer and increasing dampness wind from S.E. or S.W. If thermometer is low snow.
Fall	After Northerly winds, bad tendency, wind probably shifting to South. With high or increasing temperature, winds from South or S.W., possibly rain. The barometer generally falls with a South and rises with a North wind. If the opposite happens the South wind will be dry and the weather fine, or a North wind will be strong and be accompanied by rain. Fine weather with a low barometer is usually accompanied by continued wind or rain.

Barometric Tendency is the change in atmospheric pressure during the three hours preceding an observation.

Weather Forecasting. The individual observer who understands weather rules relating to pressure changes, wind, cloud, etc., may accurately foretell weather conditions for at least twelve hours in advance.

Tints of Sky—

A Red Sky at sunset	Fine weather.
Harsh and brilliant colors at sunset	Rain.
An intense yellow sunset	Wind.
A pale yellow sunset	Rain.
A grey sunrise	Fine weather.
A red sunrise	Rain and wind.
High dawn, i.e., sunrise over a cloud bank	Wind.
Low dawn, i.e., sunrise on the horizon	Fine weather.
Exceptional visibility	Wind and rain.

Clouds—

Sharply defined clouds	Wind.
Soft ragged scud cloud	Rain.
Increasing cloudiness	Bad weather.
Small soft white cloud, high	Fine weather.
Movement of high cloud in a different direction from surface wind	Change of wind toward direction of upper cloud.

Dew formation only occurs during fine weather.

Dew. After sunrise, the temperature increases rapidly and through the process of evaporation the amount of moisture added to the atmosphere also increases and this continues throughout the day. Evaporation is more rapid in Summer than Winter.

In the evening, the ground, vegetation and other objects lose their heat by radiation to space and become colder than the overlying layer of air.

An ice pitcher, on a warm day, gives a very practical example of dew forming. On the outside, the layer of air next to the pitcher loses heat by conduction, reaches the saturation point and the water is deposited on the outside of the pitcher in exactly the same manner as dew is deposited on the ground and other objects.

Dew Point. The Dew Point is reached when the temperature of the air is so lowered that the air is holding all the moisture it can. Any lowering of this temperature will result in dew.

Fog. Dew is a direct deposition from the water vapor in the air upon solid bodies due to the fact that the temperature of the latter falls below the dew point of the air, while air itself has a temperature above that dew point. If the temperature of the air falls below the dew point, then the formation of fog occurs.

One factor in the formation of fog is the cooling of the surface underneath the air in which the fog appears.

Fog formation is more frequent at night than by day. During the day the temperature increases rapidly and evaporation is considerable. At night the temperature drops below the dew point for a certain thickness of air and the moisture is transformed into fog.

The differences of land and sea, however, are of particular interest.

The land surface is subject to great changes of temperature due to its great powers both of absorption and radiation. The extent of these changes depends upon the cloudiness of the sky. Sea surfaces on the other hand, have a very much more limited range of temperature. The fogs off the banks of Newfoundland are a typical example of the formation of fog at sea. In the region of the island, the temperature of the sea water is kept cool by reason of cold currents from the Arctic flowing into it. In the Summer time, it is surrounded on all sides, except the North, by considerably warmer regions. Air blowing across the banks, then, from South, East, or West, is cooled by contact with the cold waters. If the air blowing in is nearly saturated with water vapor, the cooling produced is sufficient to bring it down to its saturation point and water condenses in the air and fog is formed.

Water drop fogs are formed on land under those conditions which promote great cooling of the land surfaces with which the air is in contact. These conditions are:

(a). A light wind or a calm.
(b). A clear night sky.

The first condition acts by keeping the mass of air long enough in close proximity to the surface of the ground to enable it to become thoroughly cooled, and the second by permitting radiation space to be abundant.

The thick dark fogs characteristic of large industrial centers are caused through the atmosphere being charged with carbon deposits and the like, emitted in the smoke from numerous chimneys, and also the dust and dirt common to all large cities.

Visibility, with which haze, mist, and fog are intimately connected, is measured at Meteorological Stations by locating a number of objects, such as church towers, large buildings, etc., within definite limits of distance and determining at the time of observation which object can be seen, while the one at a great distance, which is beyond it, cannot be seen.

At night, distant lights are similarly used.

Fogs are more prevalent:

In Summer: On the Atlantic Coast of North America Northwards from Maine.

In Winter: In the Southern part of the States.

In Winter and Spring: New England and the Middle Atlantic States.

In California fogs are frequent throughout the year in the mountain districts and along the sea coast.

N. B.: Fogs are dispelled, or lifted, by the wind or by a rise in temperature.

CHAPTER XIV.

WIND CHARTS AND WEATHER MAPS.*

Monthly pilot charts of the upper air of the North Atlantic Ocean are now issued regularly. They are safe pathfinders for travel by air from the United States to Europe or vice versa. The U. S. Weather Bureau aids the Navy in this activity by furnishing prerequisite meteorological data.

Former trans-Atlantic flights have been planned without such scientific assistance. They were dangerous ''hit or miss'' ''cut and try'' trips.

The charts now issued each month by the Navy provide vital data concerning the safest courses and the most favorable flying weather of the year for such journeys.

A careful analysis and scientific study of all trans-Atlantic flights were made in the research, preparatory to the publication of the first pilot charts of the upper air. The Navy Department is equipped ideally for such operations and is authorized by law to increase maritime security in every way possible. This authorization covers surface, subsurface and air investigations. Hydrographic engineers and aerial navigators, working in cooperation with meteorological authorities of the U. S. Weather Bureau, comprise **the personnel** entrusted with these responsibilities. The surveys of flights that succeeded, as well as those that failed, resulted in the production of the present pilot charts of the upper air—sterling contributions which will aid the advancement of aviation.

The pilot charts are designed primarily for the requirements of aerial navigators and are reduced to those units which are standard in the naval aviation service. **Altitudes are recorded** in feet, the same unit of measurement in which the altimeters on the seaplanes register. Distances are recorded in nautical miles to correspond to the readings of the air speed meters of the seaplanes. Wind velocities for all altitudes have been reduced from several other units to nautical miles per hour.

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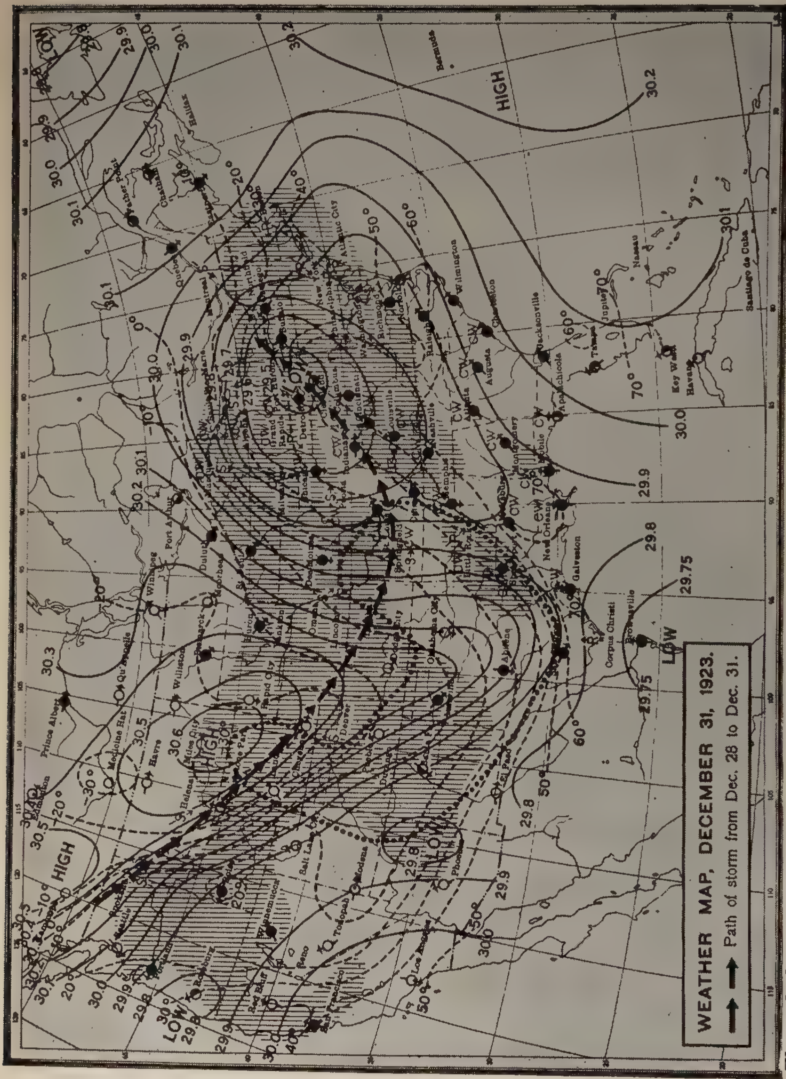
* Excerpt from the monthly magazine "Popular Aviation."


WEATHER MAP, DECEMBER 31, 1923.
Path of storm from Dec. 28 to Dec. 31.
HIGH
HIGH
HIGH
LOW
LOW
LOW
LOW

Through the courtesy of the U. S. Weather Bureau.

FIGURE 76.

Thus, the navigator planning an air trip from one of these charts can combine distances, seaplane air speed and average wind velocity by the simple process of addition, as a result of this standardization.

For the convenience of foreign nations who use the metric or other units, there is a special **conversion scale** on the side of the chart by which they can convert the U. S. Navy's pilot chart data into their own units. One of these scales combines nautical miles per hour, statute miles per hour and meters per second. Another combines inches, millibars and millimeters.

On the face of the chart, the average surface wind directions and velocities are indicated in nautical miles per hour for every five degrees of the ocean area. On account of the dearth of upper air data over the ocean areas, observations have been made at stations which surround the Atlantic Ocean, including Mitchell Field, Lakehurst, New Jersey; Washington; Hampton Roads; Due West, North Carolina; Paris Island; Pensacola; New Orleans; Groesbeck, Texas; Key West; Cocosolo, Canal Zone; Kingston, Jamaica; Santo Domingo, San Juan, Porto Rico; Teide, Canary Islands; Madrid and Barcelona, Spain, and Duindal and Dibelt, Holland. Many observations have also been recorded in mid-ocean from shipboard. Reports are to be secured from many additional shore stations, islands, and research vessels for use on future maps.

Three chief flying altitudes are registered on the chart—2,500, 5,000 and 10,000 feet respectively—each elevation being identified by a different color so that the vagaries of altitude are discernible readily. By study of these charted statistics, the aviator can determine at exactly what distance above the surface it is most desirable for him to fly at a certain time of year over a given course.

Curves showing the **air temperatures** for the month under discussion for the entire North Atlantic are prominent on the face of the map. Supplementary discussions explain how these temperatures affect the selection of safe aerial ocean routes. The **Great Circle route** from New York City to Europe, followed by the 1927 trans-Atlantic flyers in December, is unsafe because of prohibitive temperatures. Near Nova Scotia or Newfoundland, the average December temperatures fall below 30 degrees Fahrenheit, while the actual day to day readings are even much lower. Successful long distance flights at those low temperatures are impossible.

It is possible, however, even during the month of December, to fly from New York City to London. The route to be followed as indicated on the new Navy Department chart is safe, but is considerably longer than the more direct Summer air lane. This **December route** extends from New York City to Bermuda, a lap of 681 nautical miles. It has an average low temperature off New York City for the month of 40 degrees Fahrenheit, with the thermometer reading rising rapidly in flying toward Bermuda. The average at Bermuda for December is 65 degrees. The second leg of this air trip is from Bermuda to the Azores, a distance of 1,790 nautical miles. The average temperatures over this stretch of the journey will approximate those near Bermuda. The last leg of the air voyage would cover 1,286 nautical miles from the Azores to Portland, England, not far from London. The temperature decreases over this route to an average minimum of about 45 degrees Fahrenheit at Portland.

The effect of the ocean currents on air temperatures is illustrated aptly at Glasgow, Scotland. Although Glasgow is 1,000 miles north of Washington, D. C., it has the same average December temperature as the American Capital, despite that this Scotch city is located in the latitude of Labrador. The temperature tempering influence of a warm ocean current effects this weather miracle.

The U. S. Navy, through its Hydrogaphic Office, secures monthly **ocean temperature data** from 3,800 international ships at sea which ply both the main-traveled and the more remote traffic lanes. These important data are of fundamental importance in the compilation and publication of the pilot charts of the upper air above the Atlantic and other oceans.

The equatorial current is the source of fair winter weather in lands which it abuts; countries, which without its moderating warmth, would shake hands with greater annual frigidity. This ocean current drifting westerly up through the Caribbean Sea, flows north and south of the West Indies, clockwise around the Mexican Gulf, northerly along the South Atlantic coast as the Gulf Stream and then northeasterly across the North Atlantic Ocean. It finally divides into various sub-currents which lap the African and European coasts and spread northeasterly along the British Isles, France and Portugal. These currents are of special interest because they moderate Winter flying weather in all the regions which they penetrate.

The **mid-ocean circulation** of salt water currents follows the general circulation of the over-lying atmosphere. The center of this circulation is the notable Sargasso Sea—a current eddy where there is practically no water movement. It is easily identified by the presence of surface seaweed crusting the calm ocean.

The **effect of the Labrador** and other **cold Arctic currents** which travel southward down the Atlantic coast inside the route of the Gulf Stream, is depicted on the pilot chart by the congestion of the isotherms of both air and water between Cape Hatteras and Newfoundland. The number of foggy days in that vast fog belt is given. The most northerly air route to Europe from the United States, logically is charted to the south of this zone of foggy weather.

In the charted discussion of air travel across the South Atlantic from Africa to Brazil as presented by the U. S. Navy, air temperature and fog data are generally absent, as these factors are of little flying importance along such courses.

A number of interesting curves which can be studied in connection with the pilot chart for aviators, are taken from official publications of the U. S. Weather Bureau and include **diurnal variation in wind velocity** at different altitudes. Differences at given points in the velocity of the wind at 8 a. m., and 3 p. m., are given as illustrations. One curve shows the amount the wind increases in nautical miles per hour from the surface to an altitude of 20,000 feet for North Atlantic, Middle Atlantic, East Gulf and West Gulf sections. A second curve illustrates what this variation amounts to in any particular surface direction. A fourth graph shows the angular change in the wind's direction with altitude. Yet another graph shows the reduction of temperature with increased altitude. All these diagrams are explained further in tabular form. Storm tracks for December are presented in the form of a ten-year average, both over the land and ocean, with the average daily rate of storm movement expressed in nautical miles.

The average barometric pressure of the Atlantic Ocean for December is presented graphically in a special insert chart. Another chartlet, never previously published, is found on the back of the pilot chart. In the production of this invaluable chartlet, the Hydrographic Office was assisted by radio experts of the Bureau of Engineering and Naval Communications. It shows the night and day receptive range of all stations in the area of the pilot chart which broadcast weather forecasts in synoptic form.

From this and similar charts, some of the problems of the **world weather map**—the ideal dream of all meteorologists—may be studied. As matters now stand, these weather broadcasts are in different codes. Potential adjustments and improvements are anticipated, as the International Radio Conference which met in Washington recently, has endorsed a universal code and a world organization in the dissemination of weather news through the ether.

Under current circumstances, if an aviator were to fly from Bermuda to the Azores and thence to Lisbon, the **radio weather reports** broadcasted within his range would include American, German and International codes as well as several others. Confusion, chaos and loss of time results from this unstandardized condition of synoptic weather broadcasts. The information is of such nature that it can be plotted simultaneously and thus be useful "as is" to the aviators of all countries. The standardization of these data will be a forward step toward that desired eventuality—an international weather map. Today, there is no other issue of similar importance under the sun, upon which the countries of the world are more dependent than universal weather reporting.

For the benefit of European aviators who may, in the future fly to the United States, the Navy has briefed its upper air charting program. It records the number of charts completed and contemplated. The variation of the compass over the Atlantic Ocean is also given, as well as the locations of the various steamship lanes.

A case in point of the **measurable value** of the **pilot chart** to aerial navigators is had in the variations in wind direction at different altitudes off New Orleans. In the West Gulf of Mexico, practically no surface winds sweep from the Southwest quadrant, but the southwesterly and westerly winds increase at 2,500 and 5,000 feet altitudes. At an elevation of 10,000 feet above the sea level, no winds are recorded in the Easterly quadrant while 36 per cent. of the winds come from the Southwest. The value of such indicative information to an aviator is self-apparent.

The U. S. Navy does not consider its first year charts of the upper air as perfect productions by any means. These charts are pioneers, developed without either traditions or precedents to steer by. They are the forefathers of improved charts to follow. The chart for any month is issued and distributed in season so that the aviators of all countries have the information at hand before that specified month ushers in its first day. The U. S. Navy plans in the course of time to issue accurate pilot charts of the upper air conditions above every ocean.

WEATHER OBSERVATIONS AND FORECASTS.*

Weather Bureau forecasts are based upon simultaneous observations of local weather conditions taken daily at 8 a. m. and 8 p. m., seventy-fifth meridian time, at about 200 regular observing stations in the United States, Canada, Alaska, and the West Indies, supplemented by reports from other countries. Each Weather Bureau station is operated by one or more trained observers, and is equipped with mercurial barometers, thermometers, wind vanes, rain and snow gages, and anemometers, and many of them with sunshine recorders, barographs, thermographs and other devices which make a continuous automatic record of the local weather conditions and changes. The results of the twice-daily observations are immediately telegraphed to the central office at Washington, D. C., and other forecast centers where they are charted for study and interpretation by experts trained to forecast the weather conditions that may be expected to prevail during the following 36 to 48 hours. A complete telegraphic report includes the following data: Temperature, pressure (reduced to sea level), precipitation, direction of wind, state of weather, current wind velocity, clouds, and maximum or minimum temperature since last observation. From these data the forecaster, by comparison with preceding reports, is able to trace the paths of storm areas and forecast their subsequent courses and the attendant weather conditions.

The system for the **collection and distribution of** telegraphic reports of observations is so arranged that the principal stations in the United States receive reports from a sufficient number of other stations to represent the general weather conditions over a considerable portion of the country.

* Excerpt from pamphlet issued by the U. S. Weather Bureau.

A careful comparison of the forecasts with the weather for the periods covered show a **verification** of between **85 and 90 per cent.**

Weather services similar to that of the United States are maintained by the Canadian and Mexican Governments, and by a system of **interchange daily reports** are received from a number of stations in those countries. Daily observations are also received from the Azores, Iceland, Greenland, the Faroe Islands, Great Britain, Germany, France, Portugal, European Russia, Holland, Denmark, Norway, Sweden, Spain, China, Japan, the Philippines, Hawaii, and Alaska, so that the field represented by the daily reports extends over practically the entire Northern Hemisphere.

Forecast centers are located at Washington, D. C.; Chicago, Ill.; New Orleans, La.; Denver, Colo.; and San Francisco, Calif., at which both morning and evening forecasts are prepared, and centers for limited and special service at Juneau, Alaska, and San Juan, P. R. The States comprised within the five principal forecasting districts are as follows:

- Washington, D. C.:
  - Northern New England (Maine, New Hampshire and Vermont).
  - Southern New England (Massachusetts, Rhode Island and Connecticut).
  - New York.
  - Pennsylvania.
  - New Jersey.
  - Delaware.
  - Maryland.
  - District of Columbia.
  - Virginia.
  - Michigan.
  - Wisconsin.
  - Missouri.
  - Iowa.
  - Minnesota.
  - North Dakota.
  - South Dakota.
  - Nebraska.
  - Kansas.
- New Orleans, La.:
  - Louisiana.
  - Arkansas.
  - Oklahoma.
  - Texas.

  - North Carolina.
  - South Carolina.
  - Georgia.
  - Florida.
  - Alabama.
  - Mississippi.
  - Tennessee.
  - Kentucky.
  - West Virginia.
  - Ohio.
- Chicago, Ill.:
  - Illinois.
  - Indiana.
- Denver, Colo.:
  - Montana.
  - Wyoming.
  - Colorado.
  - Utah.
  - Arizona.
  - New Mexico.
- San Francisco, Calif.:
  - California.
  - Nevada.
  - Idaho.
  - Oregon.
  - Washington.

Distribution of Forecasts—Within **two hours after** the morning observations have been taken the forecasts are telegraphed from the forecast centers to about 1,200 principal distributing points, whence they are further disseminated by telegraph, telephone, radio, and mail. The forecasts reach nearly 90,000 addresses daily by mail, the greater part being delivered early in the day and none later, as a rule, than 6 p. m. of the day of issue and are available to more than 5,500,000 rural telephone subscribers within an hour of the time of issue.

This system of forecast distribution is wholly under the supervision and mainly at the expense of the Government, and is in addition to and distinct from the distribution effected through the press associations and practically every daily newspaper published in the United States.

Weather Maps and Bulletins—The weather maps are mailed immediately after the morning forecast is telegraphed. On these maps the salient features of current weather conditions, temperature, and air pressure distribution throughout the country are graphically presented. The maps also contain the numerical values of temperature, precipitation, etc., from the observing stations, and in addition a small amount of text describing concisely the main features presented by the map.

In order that all sections of the country may receive weather data, maps containing the data in tabular form are issued from about 47 of the larger stations. The maps issued at Washington and other forecast centers contain detailed forecasts for the respective forecast districts, while other station maps and bulletins contain forecasts only for the States and localities in which they are distributed.

The bulletins contain practically the same data and information as the weather maps without graphic presentation on charts. These bulletins are issued at about 85 stations.

In addition to the maps before described, a **small weather map** is printed in the **newspapers** of a few cities from a cast made by the Weather Bureau at its nearest local office. Inasmuch as the map is necessarily of diminutive proportions, and since the newspaper publishing it cannot find it practicable, as a rule, to give up the space to publish the numerical values on which the map is based, the bureau does not encourage the issue of newspaper weather maps.

Extension of Forecast Period—Within the last few years the area from which meteorological reports are received daily by telegraph, cable, and radio has been extended to cover practically the **entire Northern Hemisphere.** By means of the greater survey of atmospheric conditions afforded by these reports it is possible to forecast important weather changes for a week in advance with a fair degree of accuracy.

The Weather Bureau does not attempt to make weather forecasts for longer periods ahead. The subject of **long range forecasting** is one that has engaged the attention of its scientists for many years and thus far no laws of weather sequences have been discovered whereby reliable weather forecasts for long periods in advance can be made. Reputable scientists throughout the world agree that the development of meteorological science, up to the present time, does not admit of the making of forecasts of this character that are at all trustworthy.

WEATHER BUREAU STATIONS.

Abilene, Tex.
Albany, N. Y.
Alpena, Mich.
Amarillo, Tex.
Anniston, Ala.
Apalachicola, Fla.
Asheville, N. C.
Atlanta, Ga.*||
Atlantic City, N. J.
Augusta, Ga.
Austin, Tex.

Baker, Ore.
Baltimore, Md.*
Binghamton, N. Y.
Birmingham, Ala.
Bismarck, N. Dak.*
Block Island, R. I.
Boise, Idaho.*||
Boston, Mass.*||
Broken Arrow, Okla.†
Brownsville, Tex.
Buffalo, N. Y.
Burlington, Vt.||
Bellefonte, Pa.

Cairo, Ill.
Canton, N. Y.
Cape Henry, Va.
Charles City, Iowa.
Charleston, S. C.
Charlotte, N. C.
Chattanooga, Tenn.
Cheyenne, Wyo.*||
Chicago, Ill.||
Cincinnati, Ohio.
Cleveland, Ohio.||
Columbia, Mo.*
Columbia, S. C.*
Columbus, Ohio.*
Concord, N. H.
Concordia, Kans.
Corpus Christi, Tex.

Dallas, Tex.
Davenport, Iowa.||
Dayton, Ohio.
Del Rio, Tex.
Denver, Colo.*||
Des Moines, Iowa.*
Detroit, Mich.||
Devils Lake, N. Dak.
Dodge City, Kans.
Dubuque, Iowa.
Due West, S. C.†
Duluth, Minn.

Eastport, Me.
Elkins, W. Va.
Ellendale, N. Dak.†
El Paso, Tex.
Erie, Pa.
Escanaba, Mich.
Eureka, Calif.
Evansville, Ind.

Fort Smith, Ark.
Fort Wayne, Ind.
Fort Worth, Tex.
Fresno, Calif.

Galveston, Tex.
Grand Haven, Mich.
Grand Junction, Colo
Grand Rapids, Mich.
Green Bay, Wis.
Greenville, S. C.
Groesbeck, Tex.†
Greensboro, N. C.

Hannibal, Mo.
Harrisburg, Pa.
Hartford, Conn.
Hatteras, N. C.
Havre, Mont.||
Helena, Mont.*
Honolulu, Hawaii.*
Houghton, Mich.
Houston, Tex.*
Huron, S. Dak.*

Indianapolis, Ind.*
Iola, Kans.
Ithaca, N. Y.*||

Jacksonville, Fla.*||
Juneau, Alaska.*

Kalispell, Mont.
Kansas City, Mo.||
Keokuk, Iowa.
Key West, Fla.||
Knoxville, Tenn.||

La Crosse, Wis.
Lander, Wyo.
Lansing, Mich.*
Lewiston, Idaho.
Lexington, Ky.
Lincoln, Nebr.*
Little Rock, Ark.*
Los Angeles, Calif.||
Louisville, Ky.*
Ludington, Mich.
Lynchburg, Va.

Macon, Ga.
Madison, Wis.
Manteo, N. C.
Marquette, Mich.
Medford, Oreg.‡
Memphis, Tenn.||
Meridian, Miss.

WEATHER BUREAU STATIONS

Miami, Fla.
Miles City, Mont.
Milwaukee, Wis.*
Minneapolis, Minn.*
Mobile, Ala.
Modena, Utah.‖
Montgomery, Ala.*
Moorhead, Minn.

Nantucket, Mass.
Nashville, Tenn.*
New Haven, Conn.
New Orleans, La.*‖
New York, N. Y.‖
Norfolk, Va.
Northfield, Vt.
North Head, Wash.
(P. O. Ilwaco, Wash.)
North Platte, Nebr.

Oklahoma City, Okla.*‖
Omaha, Nebr.‖
Oswego, N. Y.

Palestine, Tex.
Parkersburg, W. Va.*
Pensacola, Fla.
Peoria, Ill.
Philadelphia, Pa.*
Phoenix, Ariz.*
Pierre, S. Dak.
Pittsburgh, Pa.
Pocatello, Idaho.
Pomona, Calif.§
Port Angeles, Wash.
Port Arthur, Tex.
Port Huron, Mich.
Portland, Me.
Portland, Oreg.*
Providence, R. I.
Pueblo, Colo.

Raleigh, N. C.*
Rapid City, S. Dak.
Reading, Pa.
Red Bluff, Calif.
Reno, Nev.*‖
Richmond, Va.*
Rochester, N. Y.
Roseburg, Oreg.
Roswell, N. Mex.
Royal Center, Ind.†
Redding, Calif.

Sacramento, Calif.
St. Joseph, Mo.
St. Louis, Mo.‖
St. Paul, Minn.‖
Salt Lake City, Utah.*‖
San Antonio, Tex.
San Diego, Calif.
Sandusky, Ohio.
Sandy Hook, N. J.
(P. O. Fort Hancock, N. J.)
San Francisco, Calif.*‖
San Jose, Calif.
San Juan, Porto Rico, W. I.*‖
Santa Fe, N. Mex.*
Sault Sainte Marie, Mich.‖
Savannah, Ga.
Scranton, Pa.
Seattle, Wash.*‖
Sheridan, Wyo.‖
Shreveport, La.
Sioux City, Iowa.
Spokane, Wash.‖
Springfield, Ill.*
Springfield, Mo.
Syracuse, N. Y.

Tacoma, Wash.
Tampa, Fla.
Tatoosh Island, Wash.
Taylor, Tex.
Terre Haute, Ind.
Thomasville, Ga.
Toledo, Ohio.
Topeka, Kans.*
Trenton, N. J.*

Valentine, Nebr.
Vicksburg, Miss.*

Walla Walla, Wash.
Washington, D. C.‖
Wausau, Wis.
Wichita, Kans.
Williston, N. Dak.
Wilmington, N. C.
Winnemucca, Nev.
Wytheville, Va.

Yankton, S. Dak.
Yellowstone Park, Wyo.
Yuma, Ariz.
Yakima, Wash.

Forecast centers in bold-faced type.
*Climatological section center.
‡Commercial airways station.
†Aerological station.
§Fruit-frost station.
‖Also pilot balloon observations.

CHAPTER XV.

DEFINITIONS.

Air Speed is the speed of an aircraft through the air. It is independent of the motion of the air.

Air Speed Indicator. An instrument used on an Airplane for registering the Air Speed.

Altimeter. A refined aneroid barometer, on which the dial is graduated in Units of Height above the ground instead of Units of Pressure. It is subject to errors due to changing barometric pressure during a flight.

Agonic Lines. Lines joining places where variation is zero, or where the compass needle points True North.

Axis. The Axis of a Sphere or Spheroid is the diameter passing through the North and South Poles.

Bearing. The angle measured clockwise from a certain fixed line to any point distant from that line. It may be either True or Magnetic.

Bearing True. The angle measured from the True Meridian to any distant point.

Bearing Magnetic. The angle measured from the Magnetic Meridian to any distant point.

Bearing Reciprocal or Back Bearing. A Bearing from an observer's position to a distant object expressed as the bearing from the object to the observer. It is equal to the forward bearing plus 180°.

Bearing Mercatorial. Is the angle at the observer between his meridian and a Rhumb Line joining him to the object.

Bearing Plate. An instrument by which bearings of distant objects may be taken, Drift calculated and the Ground Speed obtained.

Circles. A Degree of Latitude and a degree of Longitude is a square, the sides of which measure 60′; but at 60° N or S, take one degree of Latitude and Longitude and it will be seen the North and South line measures 60′, while the E. and W. measures only 30 miles. Therefore, as the circle is reduced, so also is the size of the degree.

Chart. A Chart is a representation of a portion of the surface of the Globe showing a much larger proportion of water to land, and is adapted to the requirements of mariner or seaplane pilot.

Compass. A magnetic instrument used for the purpose of orientation, for maintaining a course in the required direction, and for fixing the position of the airplane on a map or chart by means of bearings of distant objects.

Compass Liquid. An Alcohol solution with which the compass bowl is filled. It will not freeze and is used to dampen the effect of vibration upon the needles and reduce friction between the cup and pivot.

Compass Rose. Graduated Circles which are printed on a Chart indicating True North and Magnetic North.

Course Compass is the angle between the Fore and Aft Axis of the airplane and the compass needle. It is measured clockwise from 0° to 360°.

Course True is the angle between the fore and aft axis of the airplane and the True Meridian. It is measured clockwise from 0° to 360°.

Course Magnetic is the angle between the fore and aft axis of the airplane and the Magnetic Meridian.

Circles Great. Any Circle whose plane passes through the center of the Sphere, dividing it into equal parts. N to S and W to E represent Great Circles. The Equator, Ecliptic and all Meridians are Great Circles.

Circles, Small. Any circle whose plane does not pass through the center of the Sphere. All Parallels of Latitude are small Circles, except on the Equator which is a Great Circle. They decrease in size as they reach the Poles.

Contours. An imaginary line running along the surface of the ground at the same height above sea level throughout its length.

Contour Maps. Maps upon which hill features are represented by contour lines or other conventional signs. They are made expressly for the representation of hill features.

Conventional Signs. Signs depicting various features of importance on the map. Their meanings are usually printed on the map under the title of "Legend."

Conversion Angle. The angle between a Great Circle and the Rhumb Line. Used in Directional Wireless.

Cocked Hat. When three position lines are used, they will generally form a small triangle. This is known as a "Cocked Hat."

Datum or Datum Level. An assumed level to which altitudes and surroundings are referred.

Dip. The Dip of a magnetic needle is the angle in the vertical plane between the horizontal and the direction of the earth's line of total magnetic force. Sometimes called magnetic inclination.

Drift. The effect of a side wind on an airplane in flight.

Drift Angle is the angle between the airplane's fore and aft line and the Track. It is measured in Degrees to the right or left of the fore and aft line.

Degree (°). A Degree is the 360th part of a circle. It is subdivided into 60′ and each minute is again divided into 60″.

Positions on a chart are fixed by reference to the Latitude and Longitude; i.e., so many degrees E or W of the Prime Meridian and N or S of the Equator. Each Degree contains 60′ of arc.

Deviation is the angle between the Compass North and the Magnetic Meridian. It is caused by the permanent and induced magnetism of the airplane, and is only constant for one direction of flight.

Dead Reckoning (D. R.) Covers all calculations where course and distance or Latitude or Longitude depend upon data given by the Air Speed Indicator and the Compass.

Directional Wireless. A method of Navigating a course by Wireless. It is simple and accurate, and the navigator is entirely independent of terrestrial or celestial observations.

Distances. A degree is a 360th part of a circle; therefore, a degree of a large circle is larger than a degree of a small circle. On the Equator a degree of Latitude is 60′, but on the parallel of 60° it will only measure 30′ at the Equator. Exactly half.

Equator. A Great Circle on the Earth's surface equidistant from the Poles, and dividing the Sphere into the Northern and Southern Hemispheres.

Ecliptic. The Great Circle in the heavens that the sun appears to describe in a year. It is the earth's real path.

Earth Inductor Compass. Comprises three principal Units: the Inductor Generator, Direction Controller, Steering Indicator.

Fix. The point on a map or chart determined by the intersection of two or more position lines.

Form Lines. Approximate contours drawn in by eye.

Fraction Representative (R. F.). Always expressed as a vulgar fraction having the Numerator One. Its meaning is that one Unit of Length on the map represents the same units on the ground given by the Denominator.

Flight Indicator. An instrument to assist a pilot when "flying blind" in fog, clouds or at night, to keep a level and straight course.

Great Circle Flying is navigating the airplane across the sea or vast stretches of territory from one point to another, so that the Track lies on the Arc of a Great Circle.

Gnomonic Projection. A projection that shows all Arcs of Great Circles on the Sphere as straight lines on the Chart. It is principally used for long distance navigation.

Ground Speed is the actual speed of the airplane over the ground. It varies with the velocity of the wind.

Hachures. Lines drawn down the direction of the steepest slope giving the shape of the ground.

Horizontal Equivalent. The distance between contour lines on a map plotted to scale. It could be called the horizontal or level distance.

Head-Wind. A retarding wind blowing "head-on" and parallel to the line of flight. A 20 M.P.H. wind will reduce the ground speed of the airplane in like proportion.

Ice Barnacles. An accumulation of ice on airplane while in flight.

Isogonic Lines. Lines joining places of equal variation.

Induction. The magnetization of iron, steel or any other paramagnetic substance by its introduction into a magnetic field.

Interpolation. Obtaining the deviation for a course other than the eight recorded on the deviation Card.

Intersection. A Fix is where two or more position lines intersect. This is known as the point of intersection.

Latitude is the arc of the Meridian intercepted between the place and the Equator. It is measured in Degrees, Minutes and Seconds up to 90° North or South of the Equator.

Latitude, Difference of. The Angular distance between the latitudes of two places measured on a Meridian.

Latitude, Parallel of. Small circles parallel to the Equator.

Longitude is the arc of the Equator intercepted between the Prime Meridian and the Meridian of the observer's position. It is measured in Degrees, Minutes and Seconds from 0° to 180° East and West of the Prime Meridian.

Longitude, Difference of. The Arc of the Equator between the Meridians passing through two places.

Layer Tints. A method by which Hill Features are represented on a map.

Legend. An explanation of the Conventional Signs on a map. It may also be described as the Key to the map or chart.

Lubber Line. A small internal mark or line on the compass face. It indicates the direction of the airplane's head in relation to the direction of the North seeking ends of the needles attached to the card.

Lag is the difference in Altimeter reading when ascending and descending. Most altimeters are accurate when climbing, but will often read 5/600 ft. after the airplane has landed. The reading "Lags" behind the actual height.

Magnetic Variation. The Angle between the True and Magnetic Meridians at any place, named East or West, according as the Magnetic Needle points East or West of the True Meridian. N. B.—Variation is not the same throughout the world.

Magnetic Attraction, Local. The deviation of the magnetic lines of force of the earth from their natural direction owing to the presence of metal ores in the neighborhood, such as iron, cobalt, nickel. In some districts the attraction is strong enough to render a compass practically useless.

Magnets, Natural. Are found in the form of lodestone and certain iron ores, and are never used for compass adjustments, since they vary greatly in strength.

Magnets, Artificial. Are pieces of iron or steel to which magnetic properties have been imparted by various methods.

Magnetic Poles. The Magnetism of the Earth at the North Magnetic Pole is called Blue Magnetism, and at the South Pole Red Magnetism.

Magnets, Compass. The "Needle" is the compass magnet and the North seeking end is the "Red" end of the magnet.

Magnetic Equator. If those places on or near the Equator where the needle lies horizontally are joined by an imaginary line around the earth, this line will represent the "Magnetic Equator."

Magnetic Latitude is indicated by the angle which a freely suspended magnet makes with the horizontal.

Magnets, Compensating. Small magnets used in a compass for correcting deviation.

Mercator's Projection. The majority of charts used for Navigation are on Mercator's Projection, all Meridians being drawn as straight lines at right angles to the parallels of latitude, which are also shown as parallel straight lines.

Meridian is a Great Circle on the Earth's surface passing through the North and South Poles.

Meridian, Prime, is the Meridian from which Longitude is measured. For this purpose the Meridian at Greenwich is accepted by most countries for general navigation purposes.

Map. A map is a representation of part of the Earth on a flat surface, drawn to scale. Its most important requirement is that distances and bearings are accurate.

Map, Scale of. All maps are drawn to scale; i.e., a certain distance on the ground is represented by a proportionate distance on the map.

Map Distortion. The exaggeration of important features on a map to the exclusion of minor features.

Map Relief. The method by which Hill features are shown on a map.

Meridional Parts. For any Parallel of Latitude are the number of minutes of Longitude measured on a Meridian from the Equator to that Parallel of Latitude on a Mercator's Chart.

Northerly Turning Error. Temporary deviation in the compass caused by over-banking an airplane.

Navigation Lights. Port, Starboard and Tail lights attached to an airplane for use at night.

Orienting. Or, setting the map, is the process of placing the map so that the North line on the sheet points North.

Projection is the name given to methods of representing the correct surface of the earth on a plane surface, such as a map.

Plotting. The process of laying down on paper field observations and measurements. Also the process of calculating the course to steer.

Poles. The Poles of the Earth are the two points at which the axis of the earth meets the surface. They are defined as North and South Poles.

Position Line is a line obtained from observation on a terrestrial object or celestial object somewhere on the line it is known the airplane must be.

Parallelogram of Velocities. The method employed to calculate the effect of the wind on an airplane in flight.

Quadrantal Error. Deviation on the Quadrantal Points due to the presence of soft iron in the plane.

Radius of Action. Is the farthest distance which an airplane can travel on any course and have sufficient fuel to enable it to return to a pre-arranged landing ground.

Rhumb Line. The line cutting all the Meridians it crosses at the same angle. A Rhumb Line therefore, should there be no wind, is the track of an airplane steering a constant course. On Mercator's Projection all straight lines are Rhumb Lines.

Run. The direction and distance over the ground which the airplane travels between two given instants.

Rotating Compass. An apparent error in the compass card which appears to be rotating, when in reality the airplane is turning about the card.

Sphere is a solid body bounded by a uniform round surface, every point of which is equi-distant from a certain point within it called the center.

Spot Height. Definite points shown on a map with the exact height above sea level printed against them.

Swirl. A disturbance of the liquid in the compass, causing the compass card to "Carry off" in the direction of the "Swirl."

Swinging Base. A suitable radius marked out on the ground for the purpose of correcting the compass for deviation.

Swinging the Compass. The process of adjusting the compass and determining the deviations remaining in it when fixed in the airplane.

Track. The Track is the line on the map or Chart along which the airplane is travelling.

Track Angle is the angle which the track makes with the True Meridian measured clockwise from 0° to 360° from the Meridian.

Triangle of Velocities. Provides a graphical solution of the various problems arising from the effect of wind on an airplane in flight.

Transit. When two objects on the earth's surface appear to an observer to be in line with him, they are said to be in transit.

Time Scale. A scale drawn up previous to flight, giving the expected time of arrival at different points along the route.

Tail Wind. A wind blowing parallel to and directly on the tail of the airplane. A "Helping-Wind," it increases the Ground Speed of the Airplane; i.e., a 20 M. P. H. wind will increase the speed of the airplane accordingly.

Velocity. Is the rule of change of position in a given direction so that it involves both speed and direction.

Vertical Interval. The difference in elevation, on a map, between adjacent contour lines (planes).

METEOROLOGY.

Atmosphere is an envelope of gas surrounding the Earth. It has neither taste, visibility or odor.

Air Pressure. The most important of all the Meteorological elements. It decreases with altitude. The air at sea level, weighted down by the air above it, exerts a pressure of nearly 15 lbs. per square inch of surface against which it presses.

Anti-Cyclone. An area of High Pressure, generally brings clear, calm weather; though dull, over-cast skies are not uncommon in Winter.

Aeronautical Meteorology. That particular part of Meteorology dealing with weather, wind and climatic conditions of particular interest to the aviator.

Absolute Humidity. The actual amount of water vapor in the air is called the "Absolute Humidity" of that air.

Barometer. An Instrument used for recording air pressure.

Bumps. Often misnamed Air Pockets, due to extremes of heat or cold and wind. They may be described as ground bumps or cloud bumps.

Condensation. The passage of the moisture of the atmosphere from the invisible gaseous form, water vapor, into some visible, solid or liquid form.

Conduction. The transference of heat from one body to another, or part of one body to another part.

Convection. The transference of heat from one point to another by circulation. The warm air rises, expands and grows cooler at the rate of 16° F. for each 300 ft.

Cyclone. A Low Pressure Area where the temperature is lower than in the surrounding parts. It is accompanied by rain and storms.

Clouds. A pocket of warm, moist air, forced to rise due to convection. As the pocket of air rises it expands, cools off rapidly and the water vapor is condensed and clouds are formed.

Col. An area of almost uniform pressure between two highs and lows.

Dew. The condensation of water vapor in the form of liquid water. A direct deposition upon solid bodies due to the fact that the temperature of these bodies becomes colder than the over-lying layer of air.

Dew-Point. The Dew-Point is reached when the temperature of the air is so lowered that the air is holding all the moisture it can.

Evaporation. The change from a solid or liquid state is called evaporation. It is the opposite to condensation.

Fog. Fog is a cloud in the lower air in contact with the earth, and is caused by the temperature of the air falling below the dew-point. It is more frequent at night than by day.

Gradient Wind. A wind at about 2/3000 feet above the ground level, where the direction is practically parallel to the Isobars and the velocity is not influenced by ground objects.

Humidity. Refers to the moisture in the atmosphere. The proportion varies according to the place and time.

High Pressure Area. (An Anti-Cyclone.) It is associated with calm weather, clear skies, High Temperature.

Insolation. The radiant energy, which in the form of ether waves, reaches the Earth and warms it.

Inversion of Temperature. The reversal of the normal Vertical Gradient of Temperature in the atmosphere; an increase of temperature with increase of altitude.

Inversion of the Wind. At the surface of the Earth, the wind drops towards nightfall; with altitude, the reverse is the case. This is known as Inversion of the wind.

Isobars. Lines connecting all points having the same atmospheric pressure.

Isotherms. Lines connecting all points having equal temperatures.

Line Squall. A sudden violent wind, accompanied by a long line of dark cloud with rain or hail.

Low Pressure Area. (Cyclone.) An area of storms and rains with rising temperature as the cyclone approaches.

Periodic Winds. Winds which do not depend on the general or secondary circulation of the atmosphere.

Planetary Winds. Those winds which blow on any Planet rotating from West to East on its Axis and that are heated at the Equator.

Prevailing Winds. Winds that blow constantly from one direction during the greater part of the year. The prevailing Westerlies of the Southern Hemisphere are an example.

Precipitation. The fall of condensed moisture in the form of rain, sleet, hail or snow.

Relative Humidity is the proportion of the actual amount of water vapor present in the air to the amount which the same volume of air would hold if it were saturated.

The Stratosphere. The upper region of the atmosphere. An area of calm weather.

Squall. A Squall is a blast of wind of higher velocity than has been expressed on the average. It dies away very suddenly.

Synoptic Chart. A Weather Map showing the meteorological conditions over that region at a given time.

Tropopause. The line dividing the atmosphere into Upper and Lower regions.

Troposphere. The Lower region of the atmosphere. An area of storms and changing weather conditions.

Wind is the motion of the air and is due to the unequal warming of different parts of the earth by the sun. It is stronger by day than by night.

QUESTIONS AND PROBLEMS

CHAPTER I

MAPS.

1. What is **"Air Pilotage"**?

2. Explain what a map represents and the purpose for which it is used.

3. Give two examples of a scale on a map and explain its use.

4. What is meant when speaking of a Representative Fraction?

5. On a Map, hill features are shown by various methods. Name three of them.

6. Define **Vertical Interval** (V. I.) and **Horizontal Equivalent** (H. E.). Also, state how you would judge the steepness of a hill from the contour lines.

7. What is meant by:

(a) A six-inch map.
(b) A 10-mile map.
(c) Which of the two maps is a small scale map?

8. By what method would you determine the gradient of a hill from the map?

9. What do the following figures represent?

R. F. 1/12672; R. F. 1/126,720

Convert them into a scale of miles.

10. How many Centimeters are there in a Kilometer; and how many Kilometers to a mile?

11. Give the number of feet in a Statute Mile and a Nautical Mile.

12. State the use of the Protractor and the Dividers.

13. Explain how you would orient the map and what North Point you would use.

14. How are bearings measured or taken; and by what means would you measure the distance between the point of departure and the destination?

15. The scale of the map is R.F. 1/1,584,000. Give the bearings and distances from: Chicago to Milwaukee; Boston to Hartford; New York to Washington; using the Rand McNally Air Map in plotting.

CHAPTER II AND CHAPTER III.

CHARTS, LATITUDE AND LONGITUDE.

1. Give a definition of a Chart and explain for what purpose it is particularly adapted.

2. On what projection are the majority of Charts constructed?

3. How are positions fixed on a chart and measurements arrived at?

4. What is the length of a degree of Longitude at the Equator and at Latitude 60°, and what scale must always be used for measuring distance?

5. What is a projection?

6. Draw a diagram showing the relative sizes of areas enclosed by 1° of Latitude and 1° of Longitude on the Earth, and as represented on a Mercator's Chart.

7. In the construction of a Mercator's Chart, what methods are adopted to prevent distortion?

8. What is a Meridional Point, and how is it applied in the construction of a Mercator's Chart?

9. What particular purpose do charts constructed on the Gnomonic Projection serve?

10. In plotting a course on a chart, when would you use Great Circle Flying in preference to Rhumb Line Flying?

Plot two courses, of approximately 2500 miles and 5000 miles respectively, showing the percentage of distance saved by following the Great Circle.

11. Define Great Circle Flying and Rhumb Line Flying.

12. Why is the Rhumb Line Track preferable to the Great Circle Track?

13. What is a Compass Rose?

14. Before plotting a course on a chart what particular points do you look for?

15. What is the Prime Meridian and in what Latitude and Longitude is it situated?

16. Describe the shape of the Earth.

17. Where is the variation represented on the chart? How do you know whether a Chart is True or Magnetic?

18. Define the following:

> (a), The Equator; (b), Great Circle; (c), Small Circle; (d), Prime Meridian; (e), Parallels of Latitude; (f), The Poles.

19. How are Latitude and Longitude measured? In what terms of measurement are they expressed?

20. Explain the method of converting Time into Arc and vice versa.

> (a) Change 58°, 20′, 40″ into time.
> (b) Change 8 hrs., 38′, 20″ into Arc.

21. What is the difference in Latitude and the difference in Longitude between point of departure Lat. 50°, 18′ N. Long. 45°, 30′ W.; and Lat. 15°, 30′ N. Long. 30°, 45′ E.?

22. How many minutes and seconds are there in a degree?

23. What is the difference in time between a place Long. 78°, 30′ W. and the time at Greenwich?

24. What period of time does it take for the sun to travel 90° around the earth?

25. With the aid of a map plot out the difference in time between: New York and London; Chicago and Los Angeles; San Francisco and Hong Kong; Berlin and Constantinople.

CHAPTER IV.

MAGNETIC VARIATION, DEVIATION and BEARINGS.

1. What is Magnetic Variation and how does it affect the compass needle?

2. What is meant by Agonic Lines and Isogonic Lines? When reading a Magnetic chart, how will you find the Magnetic Variation for any particular place?

3. Give the application of variation when correcting True Bearings to Magnetic Bearings and vice versa.

4. How is the Magnetic North represented on a map?

5. Work out the following examples:

(a) The True Course is 90°, Variation 6° W. What is the Magnetic Course?

(b) The Magnetic Course is 125°, Variation 9° E. What is the True Course?

6. How is Deviation applied to the Magnetic Course and from what North Point is it calculated?

7. Work out the following examples:

(a) True Course, 235°, Variation 4° E, Deviation 2° W. Find Compass Course.

(b) Compass reads 25°, Variation 10° W, Deviation 7° W. What is the True Course?

(c) True Course 185°, Magnetic 200°, Compass Course 196°. Find Variation and Deviation.

(d) What is the True Course corresponding to a compass course of 328°, Variation 4° E, Deviation 8° W?

8. Draw a diagram illustrating an angle of variation 15° W. and an angle of deviation 6° E. If the True Course was 359°, what would the compass course read?

9. Give an example of a Deviation Card for eight points of the Compass, showing three Easterly deviations and five Westerly.

10. What effect has the metallic substance, in a plane, on the compass card?

11. What is Deviation?

12. If the forward bearing from A to B is 206°, what would the back bearing read?

13. How do you explain compass error?

14. How is Deviation affected by change of course?

15. Define True Bearing, Magnetic Bearing, Compass Bearing.

CHAPTER V.

DRIFT, DEAD RECKONING, RADIUS OF ACTION.

1. What is meant by the term "Drift," and how does it affect the progress of a plane through the air?

2. In the absence of weather reports, what steps are taken to determine the amount of drift and the velocity of the wind?

3. In making calculations for counteracting the effect of Drift, what principle is involved?

4. Explain what is meant by:

(a) Track and Ground Speed.
(b) Define Track and Track Angle.

5. Give a definition of velocity and how it is represented.

6. What is the course to steer to make good the desired Track: Magnetic Course 112°, Wind 20 M.P.H. 269°, Air Speed 70 M.P.H.

Find the velocity and direction of the wind: Magnetic Course 85°, Air Speed 95 M.P.H., Track 60°, Ground Speed 75 M. P. H.

7. What calculations are required when steering a course by Dead Reckoning?

8. The Ground Speed is 95 M.P.H. and the distance from A to B is 340 miles. How long will it take to reach the point B?

9. What is Radius of Action, and when making calculations what does the margin of safety refer to?

10. In the formula employed, what do the following letters represent: R, P, O, H?

11. Find the radius of Action of an airplane along a track 142° True, Air Speed 90 M.P.H.; Wind from 60° True, 30 M.P.H. Fuel for 7 hours.

12. Given the radius of Action as above, after one hour's flight the wind increases to 45 M.P.H. When would be the time to turn?

13. Give the formula for calculating Ground Speed; the distance covered in 20 minutes is 45 miles.

14. What relation is Ground Speed to Track Flown?

15. Is the Air Speed registered on the Air Speed Indicator affected by a Head Wind?

CHAPTER VI.

DIRECTIONAL WIRELESS.

1. What is Directional Wireless, and for what purpose is it used?

2. Draw a diagram showing the ideal position of the airplane in relation to the Wireless Stations.

3. How is the Latitude and Longitude of an airplane in flight calculated?

4. If the airplane is equipped with a transmitter, how would the pilot locate his position?

5. What useful purpose does the pointer serve?

6. If the signal from one base station is considerably stronger than that from the other, what would the pilot infer?

7. How do wireless waves travel?

8. If the airplane be equipped with a transmitter, does the pilot require a direction finder? Explain why your answer is in the affirmative or negative.

9. What is meant by the Conversion Angle?

10. In order to find the Conversion Angle, what information is required?

11. Where does the possibility of error arise in locating position on the chart, and how is this corrected?

12. What is the rule for finding the Mercatorial Bearing in the Northern Hemisphere?

13. What is the value of 1/2 d. Long. in the table of variations?

14. When laying down the position line on the chart, what rule must be observed?

15. Has Directional Wireless any advantages over other methods of Navigation? If so, state what they are, and also any long distance flight on which this method was used with success.

CHAPTER VII.

FIXING POSITION.

1. What does Fixing Position refer to?

2. How are position lines designated?

3. When two objects on the earth's surface appear to an observer to be in line with him, what is the term used to denote this, and how is it entered in the Log Book?

4. How are transfer position lines distinguished?

5. What is the difference between a fix and a running fix?

6. In taking bearings, what precautions must be observed?

7. When three position lines are used, name the Triangle thus formed, and in what manner the bearing is read off.

8. How is the fix distinguished from other intersection lines?

9. The Magnetic Bearing of A at 12.15 was 320°, at 12.25 it was possible to observe another object. Track is 120° Mag-

netic, Ground Speed 90 M.P.H. Draw a diagram to scale, showing the distance travelled in 20 minutes and the transfer position line.

10. A is the point of departure; B, C, D, three fix points on which bearings are taken at 2.30, 2.35, 2.40 respectively; draw a diagram by which it is possible to determine the fix at 2.40.

11. What is the deviation to correct bearings observed?

12. When recording a fix, is approximate time sufficient?

13. How are lines of bearing plotted?

14. Preparatory to fixing position, what use does the observer make of the map or chart?

15. What conditions render it necessary to fix position?

CHAPTER VIII.

CROSS COUNTRY NAVIGATION.

1. Before leaving the ground, what should the pilot do in reference to the Altimeter?

2. What preparations are necessary before proceeding on a cross-country flight, and what information must the pilot obtain?

3. During flight, what procedure is followed to ensure the desired track being held?

4. If the pilot loses his bearings, what steps should be taken to locate his position on the map?

5. What is a Time Scale? Draw one showing six different towns en route.

6. What do you know about a "Rotating Compass"? How is it corrected?

7. A Pilot steering a course 250°, discovers he has veered 20° to the South. How will he correct this error?

8. When flying over rough, hilly country, with hills varying in height, what precautions should the pilot take?

9. What does the term "Flying Blind" signify?

10. Name some of the land-marks that are of assistance when flying at night?

11. What is a beacon light, and where are they chiefly located?

12. In case of a forced landing at night time, with a machine equipped for night flying, what steps should be taken by the pilot to avoid accident?

13. What special night-flying equipment must be carried on mail and passenger planes?

14. Should ice accumulate on the airplane and the machine he forced down, at what speed should it land?

15. What weather conditions do you consider too inclement for safe flying?

CHAPTER IX.

MAGNETISM.

1. Describe magnetism.

2. How many kinds of magnets are there; name them and explain what their properties are?

3. What kind of steel develops the most perfect magnet?

4. Explain the correct method of storing magnets, and the reason why.

5. What is the magnetism of the Earth at the Poles called? Where are they located?

6. If a magnet be suspended over a bar magnet, what positions will it take over the poles and center of the magnet?

7. Which is the Red end of a Compass Needle, and why is it so named?

8. Explain the causes of Deviation and how it influences the compass needle. How is it compensated for?

9. Is the magnetism in "Soft" iron permanent? What errors does it produce?

10. After a compass has been adjusted, explain the conditions which render it necessary for correction from time to time.

11. If it is necessary to stow magnets away, how should they be packed? State reasons.

12. Has excessive heat any effect on a magnet?

13. What effect have like poles and unlike poles upon one another? In what direction does the needle point?

14. When flying over certain areas of the earth, the compass is subject to violent changes. What is the cause of this?

15. Define the following:

(a) Angle of Dip. (b) Needle Zone.
(c) Artificial Magnets. (d) Local Magnetic Attraction.

CHAPTER X.

THE AIRCRAFT COMPASS.

1. Describe briefly the Magnetic Compass and its use?

2. How should a compass be fitted in an airplane? After a crash, what damage may you expect to find in the compass?

3. A compass bowl is filled with liquid solution. What is this composed of? Why is it necessary?

4. How is the effect of "Dip" overcome in a compass?

5. What effect has Changes of Speed and Course on a Compass?

6. Explain Northerly Turning Error.

7. How do you correct a compass for "Swirl"? What are the causes of it?

8. Describe a swinging base. When laying out a swinging base what points must be carefully observed?

9. What is meant by the term "Swinging the Compass"? Explain briefly the procedure.

10. What are the characteristics of a landing compass, and what is the connection it has with swinging the compass?

11. In what manner are the compensating magnets used? In what part of the compass are they placed? How would you reduce the strength of a magnet?

12. Name the first four corrections made on a compass.

13. When adjustment is made, or reading taken on every 15°, how is the record kept?

14. A compass card has a tendency to stick if rough usage has been experienced. What method would you use to check this?

15. Define:

(a) Pivot Friction.
(b) Bubbles.
(c) Quadrantal Error.
(d) Lubber Line.

CHAPTER XI.

INSTRUMENTS.

1. What particular purpose does an Air Speed Indicator serve?

2. The speed of the machine at half-throttle is 90 M.P.H. There is a tail-wind of 30 M.P.H. What will the Air Speed dial read?

3. Give a brief description of the Air Speed Indicator, its component parts, and adjustment in the airplane.

4. What is a bearing plate? Describe the manner in which it is fitted into the airplane.

5. It can be used for three separate and distinct purposes. What are they?

6. You wish to find the Drift Angle. What instrument would you use?

7. In checking the ground speed of an airplane, what instruments are necessary?

8. State in a few words what an Earth Indicator Compass is.

9. How many Units are comprised in the Earth Inductor Compass? Name them.

10. What advantage has an Earth Inductor Compass over that of an ordinary Magnetic Compass?

11. Describe briefly the Flight Indicator. Name the component parts and their uses.

12. If an area of bad visibility is encountered and the pilot has to fly "blind," what instrument would he be mainly dependent upon to help him steer a straight and even course?

13. What instrument used in Meteorology is allied to the Altimeter? What are the functions of an Altimeter?

14. During flight an altimeter is subject to errors. State the reason for this.

15. How accurately does the Altimeter record height when ascending and descending. What connection has "Lag" with the recording of altitude?

CHAPTER XII.

ICE ACCUMULATION ON AIRPLANES.

1. What is the action of ice on an Airplane, i. e., in what manner does it affect the performance?

2. State the ideal conditions of the atmosphere for developing ice formations.

3. In order to avoid the ice forming strata of the atmosphere, the pilot may fly close to the ground, or he may climb to a high altitude. Give the reasons for this.

4. What is the effect of ice accumulation on a propeller?

5. At what height are ice-forming clouds generally encountered?

6. What is meant by Crystallization?

7. What is sleet and in how many forms does it fall?

8. Name the cloud forms in which you would find the ice hazard.

9. Describe briefly what may happen in changing from water vapor to the solid state.

10. What is an ice-barnacle?

11. What temperatures are most conducive to ice-formation?

12. Draw a diagram, demonstrating the forming of ice on the leading edge of a wing.

13. In what part of the U. S. would you expect to meet with ice forming conditions, and at what time of the year?

14. Is there any method by which the wings of an airplane could be kept free of ice?

15. The Airplane has a landing speed of 50 M.P.H. with full load. If, through ice formation, a "forced landing" was inevitable, at what speed would you land?

CHAPTERS XIII AND XIV.

METEOROLOGY.

1. State what you know about the atmosphere and its composition.

2. Into how many regions is the atmosphere divided, and what are they?

3. By what process are Cumulus clouds formed? Draw a diagram illustrating this.

4. The atmospheric pressure at a certain place is lower than in the surrounding areas. State the after effect of this.

5. What do you know about:

(a) Humidity. (b) Saturation Point.
(c) Relative Humidity. (d) Water Vapor.

6. Under what condition is evaporation greater than at other times?

7. Describe Inversion of Temperature, and the results of any test of this atmospheric condition.

8. At what height would you expect to find Nimbus Clouds, Cirrus Clouds, Alto-Stratus, Cumulus?

9. What is the cause of wind? Describe briefly what you know about four distinct types of wind.

10. In case the pilot has to land in the face of a thunderstorm, what precautions should he take?

11. What do you know about areas of High and Low Pressure. At what speed do they move across the country?

12. Describe briefly the characteristics of two types of storms dangerous to aviators.

13. What are:

(a) Isobars.
(b) Cols.
(c) Isotherms.
(d) Synoptic Charts.

14. Preparatory to a long distant flight, what would the pilot require to know in regard to Meteorological Conditions?

15. Give a brief outline of:

(a) Fog.
(b) Dew.
(c) Barometer.
(d) Condensation.

EXTRACT.

AIR TRAFFIC RULES FROM AIR COMMERCE REGULATIONS.

Application of the law: "In order to protect and prevent undue burdens upon interstate and foreign air commerce, the air traffic rules are to apply whether the aircraft is engaged in commerce or is non-commercial, or in foreign, interstate, or intrastate navigation in the United States, and whether or not the aircraft is registered or is navigating in a civil airway."

No person shall acrobatically fly any airplane carrying passengers for hire or reward.

Right-side traffic. Aircraft flying in established civil airways, when it is safe and practicable, shall keep to the right side of such airways, keeping an interval of not less than 300 feet between them.

Crossing. When two engine-driven aircraft are on crossing courses, the aircraft which has the other on its right side shall keep out of the way and at a distance of not less than 300 feet.

Approaching. When two engine-driven aircraft are approaching head-on, or approximately so, and there is risk of collision, each shall alter its course to the right, so that each may pass on the left side of the other. This rule does not apply to cases where aircraft will, if each keeps on its respective course, pass more than 300 feet from each other.

Overtaking. An overtaking aircraft is one approaching another directly from behind or within 70 degrees of that position, and no subsequent alternation of the bearing between the two makes the overtaking aircraft a crossing aircraft within the meaning of the air-traffic rules, or relieves it of the duty of keeping clear of the overtaken craft until it is finally past and clear.

Passing when overtaking slower craft. The overtaking craft shall keep out of the way of the overtaken craft by alter-ing its own course to the right, and **not in the vertical plane,** at a minimum distance of not less than 300 feet.

Exclusive of landing and taking off, and except as permitted because of sudden danger or weather causes, aircraft **shall not be flown over the congested parts of cities,** towns, or settlements except at a height sufficient to permit of a reasonably safe emergency landing.

A plane with a gliding angle of five to one, flying above the center of a city ten miles in diameter must maintain at least 5,280 feet **altitude,** to permit a safe glide beyond city limits. In no case shall altitude over cities be less than 1,000 feet.

In open country no aircraft shall be flown at a height of less than 500 feet, except where indispensable to industrial operations.

No person shall **acrobatically fly an aircraft** over a congested area of any city, town or settlement.

No person shall fly less than 1,000 feet in height, nor shall he acrobatically fly an aircraft, without the approval of the Secretary of Commerce, **over any open-air assembly of persons.** The restricted area extends 1,000 feet in all directions from the assembly.

No person shall acrobatically fly an aircraft below 2,000 feet in height over any **established civil airway,** without the permission of the Secretary of Commerce.

No person shall acrobatically fly an aircraft at any height over any **certified airport or landing field,** or within 1,000 feet horizontally thereof, without permission of the Secretary of Commerce.

Landings shall be made up wind when practicable.

Landing rules (course). If practicable, when within 1,000 feet horizontally of the leeward side of the landing field, the airplane shall maintain a direct course toward the landing zone.

Landing rules (right over ground planes). A landing plane has the right of way over planes moving on the ground or taking off.

Landing rules (giving way). When landing and maneuvering in preparation to land, the airplane at the greater height shall be responsible for avoiding the airplane at the lower height, and shall, as regards landing, observe the rules governing overtaking craft.

(A) **Angular limits.** The angular limits laid down in these rules will be determined as when the aircraft is in a normal flying position.

(B) **Airplane lights.** Between one-half hour after sunset and one-half hour before sunrise airplanes in flight must show the following lights:

1. On right side a green light and on left side a red light, showing unbroken light between two vertical planes whose dihedral angle is 110° when measured to the right and left, respectively, from dead ahead and to be visible at least 2 miles.
2. At the rear and as far aft as possible a white light shining rearward, visible in a dihedral angle of 140°, bisected by a vertical plane through the line of flight and visible at least 3 miles.

Place and dimensions of marks. Identification marks shall be located in the lower surface of the lower left wing and the upper surface of the upper right wing. The marks shall also appear on both sides of the rudder, of size as large as the surface will permit, leaving a margin of at least 2 inches.

Except as may be authorized under sections 40 and 42, identification marks shall be located as follows:

On airplanes. On the lower surface of the lower left wing and the upper surface of the upper right wing, the top of the letters or figures to be toward the leading edge, the height to be at least four-fifths of the mean chord, provided, however, that in the event four-fifths of the mean chord is more than thirty inches, the height of the letters and figures need not be more but shall not be less than thirty inches. If the lower left plane is less than one-half the span of the upper left plane, the letters or figures thus described shall be on the under surface of the upper left plane, as far to the left as is possible. In the case of a monoplane, the marks shall be displayed on the lower surface of the left wing and the upper surface of the right wing in the manner thus described. The marks shall also appear on both sides of the rudder, of size as large as the surface will permit, leaving a margin of at least 2 inches.

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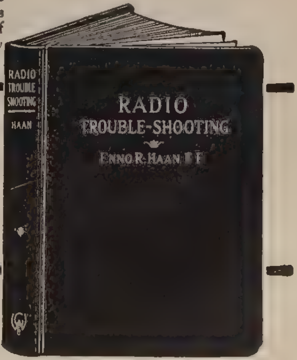

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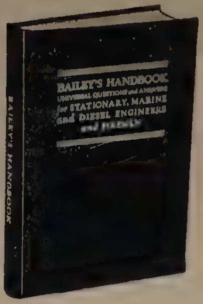
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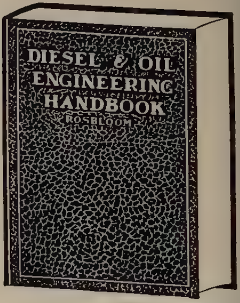

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